Intelligence, Inspection Time, and Cognitive Strategies.

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Declaration

This thesis is my own composition, and the work presented in it is my own.

ABSTRACT OF THESIS (Regulation 3.5.10)

It has been argued that the negative correlation between IQ scores and perceptual intake speed (as measured by Inspection Time (IT)), is not due to common variance between mental speed and IQ, but because of differential strategy use during IT. This thesis examined the effect of IQ and reported cognitive strategies on experimental measures of IT to test strategic theories of intelligence.

Experiments 1 and 2 considered the general claims made by strategy theorists about performance on experimental tasks; that performance strategies are driven by an executive 'metacognitive' process; that higher-IQ subjects are more likely to report strategies; that individuals who use strategies have general advantages on all tasks due to this conceptual approach; and that developing effective strategies for tasks requires a period of practice and feedback during which techniques can be refined. It was found that strategy users were not advantaged on all IT tasks, and that the IQs for subjects who reported IT performance strategies (or not) were the same. An IT task which limited practice and gave false feedback did not affect strategy reporters more than those who did not report strategies. These studies suggested that strategic effects were specific to particular IT tasks, rather than generalised to all IT measures, and were not due to metacognitive processes.

Experiments 3 and 4 investigated whether the perception and use of apparent motion cues seen after an IT stimulus was due to metacognitive processes directing the use of specific cues, or whether these cues were epiphenomenal to more basic mental processes. Both studies demonstrated that individuals who report apparent motion cues during IT tasks have shorter ITs than individuals who do not report these cues. When IT was performed in conjunction with a parallel, attention-demanding task, ITs tended to be shorter for apparent motion reporters compared to non-reporters, despite previously defined motion reporters not being able to report them during the dual-task condition. This suggested that the perception of apparent motion cues was not dependent on focussed attention to the IT task. These results were discussed in relation to theories of attentional resources.

Experiment 4 looked at the response latencies (RT) of IT and IT-like tasks, in order to measure the time taken for the assumed subcomponents of strategic processing to occur. Subtraction of the tasks from one another did not isolate a specific strategy processing stage associated with using apparent motion to guide IT discriminations. Though static measures of RT within IT did not discriminate strategy users from non-users, dynamic measures of RT within IT, based on the rate of change of RT with increasing difficulty of IT, tended to be faster for apparent motion reporters. These individuals were not faster on an unmasked version of IT. As the experiment could not identify a specific processing stage associated with the use of apparent motion, it was concluded that the perception and response to IT-related apparent motion cues were preconscious in origin.

Pooled results from experiments 3 and 4 provided a sample of 75 subjects for whom the same IT and IQ measures had been taken. The overall IT/IQ correlation (Pearson's r) was -0.39 ($P<.01$); when the sample was divided according to the reported use of apparent motion cues to guide IT discriminations or not, IT/IQ correlations were the same for both groups; r = -0.44 ($P<.01$). There was no difference in IQ between the two groups (t = -0.72, n.s.). The IT/IQ correlation is therefore not because of the inclusion or exclusion of individuals reporting apparent motion; nor does IQ account for the difference between these groups, despite IT being faster among apparent motion reporters (t = 2.97, $P<.005$).

This thesis has thus shown that perception of apparent motion cues from two-line visual IT stimuli does not reflect metacognitive processes directing the use of these cues, and that awareness of these motion cues does not disrupt the IT/IQ r. The motion seen by some subjects after poorly-masked IT stimuli is probably due to subtle differences of visual information processing and poor visual masking, rather than differential strategy use.

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Chapter One

1.1. Introduction

Though it is over 100 years since Sir Francis Galton made his original observations on intelligence, his ideas are still highly influential. Francis Galton believed that cognitive ability was evident in virtually everything one did, and that the apparently different domains of intelligence were, in fact, unitary. Intelligence was a property of simple physiological processes, which were genetically inherited, and measurable by simple tasks like reaction time or sensory discrimination (Galton, 1883; 1890). Many of Galton's speculations have been confirmed, for example the substantial heritability of IQ (Bouchard, Lykken *et al*, 1990), and the major influence of general intelligence (*g*) on the ostensibly diverse subprocesses of intelligence (Blaha and Wallbrown, 1982). Are Galton's other ideas also essentially correct?

By the turn of the century the correlation between simple perceptual processes and cognitive ability, examination marks, or teachers ratings in the classrooms had already been demonstrated (Wissler, 1901; McKean Cattell, 1890; Burt, 1909; reviewed by Deary, 1986). However this research did not inspire subsequent studies, and the approach appeared of minor interest until Cronbach made his famous address to the American Psychological Association (Cronbach, 1957). In this address Cronbach advocated the combination of the two psychological paradigms of most practical and theoretical use - experimental psychology and psychometrics - to investigate the underpinnings of human variation.

The notion that simple tests of sensory acuity, discrimination, reaction time and motor time measure biological intelligence has since returned, and now bases itself on the theory that these processes measure the underlying speed and accuracy of simple mental operations (Eysenck, 1967, 1982, 1986). Significant associations, for example, have been found between the speed at which infants form memories and their IQ at age 4 (Slater, Cooper, Rose and Morrison, 1989); for the speed at which an individual can decide which of 1, 2, 4 or 8 possible lights has been illuminated, as on the 'Hick RT task' (Jensen, 1987); and the intercept of the speed at which an individual can scan their short-term-memory for the presence or absence of a probe digit (Chiang and Atkinson, 1976). That intelligence is strongly associated with elementary cognitive processes is counter-intuitive, as products of intelligence are often the fruits of extended and cautious thought: It is this contrast between higher mental processes and simple, apparently intellect-free tasks, that the current thesis examines.

1.2. *g* and the London school of psychometrics.

Galton's idea that intelligence is unitary was confirmed by the discovery that a large battery of cognitive tests will correlate positively with one another, and that a common feature explained this (Spearman, 1904). Cattell designated this common factor of intelligence tests *g* , for general intelligence, itself divisible into two two components, fluid (*gf*) and crystallised (*gc*) intelligence. Cattell described *g* as a kind of mental energy; a basic, presumably biological, quality of the nervous system. While *gc* is a product of learning, *gf* follows a developmental pattern, increasing with age until an asymptote is reached in adolescence, declining gradually, but at an increasingly steep gradient, with age after about 40 (Salthouse, 1982). *gc* does not radically decline with age, increases with age as *gf* helps in its acquisition, and is more resistant to deterioration than *g* f. This is not without use; as measurements of *gc* such as vocabulary or word familiarity correlate highly with measures of *gf* in adult subjects. As *gc* does not reduce substantially with aging, the difference between *gf* and *gc*, as in cases of suspected dementia, can be estimated (Nelson, 1982).

Modern approaches to elucidating *g* use these experimental measures of information-processing speed to examine the correlation between simple information processing speed and performance on IQ tests (what Kail and Pellegrino (1985) imaginatively call 'the cognitive correlates approach'). Underlying this is the view that the cortex functions as a limited capacity system for processing information. The limited capacity of the information processing system restricts the amount of input from external stimuli; constrains the number of operations that can be performed simultaneously with this input; and limits the amount of information that can be retrieved from short- or long-term memory. This model places great emphasis on the speed of mental operations, slowness leading to an accumulating cognitive handicap (Eysenck, 1967; Lehrl and Fischer, 1990). The tasks, issues and theoretical models associated with this approach are summarised in the volume 'Intelligence and the Speed of Information-Processing' (Vernon, 1987).

Critics of the cognitive correlates paradigm often refer to the limited variance that such cognitive tasks share with IQ test results (Hunt, 1980). Many of the correlations between elementary cognitive tasks and IQ are in the region of 0.30; this suggests that only 9% of the variance between the two measures is actually shared. To increase the amount of variance accounted for by speed, some researchers have entered additional speed-based experimental tasks into multiple regression models; Lunneborg (1977), for instance, found a multiple correlation of 0.6 between measures of verbal aptitude and a battery of information-processing tasks. This still limits the correlation, as many of the tasks themselves correlate with each other. In addition, even weak correlates added into a multiple regression model will increase the size of the multiple correlation, irrespective of the actual correlation.

A further problem with most information-processing speed tasks is that the subject must typically make a speedy motor response to the experimental task; and even if the task records separate indices of decision and movement time, the problem of impulsivity is not fully controlled. This obstruction can be resolved if one measures cognitive speed without requesting a motor response, either by measuring an electrical potential from the brain's response to an unexpected event, as in the case of the auditory evoked potential (Donchin, 1981), or by controlling the speed with which the subject is presented with information. The latter reflects the first of Spearman's noegenic laws: the apprehension of experience (Spearman, 1927), which, over the past 15 years, has been refined into a task known as Inspection Time.

1.3. Inspection Time (IT).

IT places no importance on the speed with which a motor response is made to an IT stimulus; thus where the physically handicapped would be at a severe disadvantage on a choice-reaction time paradigm, their disability would be irrelevant to an IT session. The only constraint on perfect IT performance by any individual is the brevity of stimulus presentation, and the fact that the stimulus is backwardly masked following this exposure. IT measures some temporal limitation to the rate at which information is taken in for processing, and is defined as the lowest exposure duration at which a subject can accurately and reliably make a perceptual discrimination (Nettelbeck, 1987). A meta-analysis of results from IT/IQ studies has been conducted in which the various shortcomings of different studies (e.g.. sampling error, measurement error, and variations of range) have been corrected for. The results found that IT is negatively related to IQ, in particular performance IQ or measures of *g* f; for adults this 'true' association was estimated as -.54 (Kranzler and Jensen, 1989).

1.4. The theoretical basis for IT.

IT emerged from the cumulative processing model of perceptual discrimination (Vickers *et al*, 1972; Vickers and Smith, 1986). This theory suggests that following the sensory registration of briefly exposed stimuli, the stimulus is encoded into short-term memory. Once a critical amount of evidence has accumulated in separate perceptual registers, a decision concerning the locus of the target stimulus can be made. The theory holds that individuals differ in regard of the rate at which they execute this process, and that the minimum time for subjects to make a correct perceptual discrimination to a pre-determined level of accuracy is their IT. Brand and Deary (1982) simplify this psychophysical background to a more easily understood postulate: that IT measures the speed at which an individual takes in information.

1.5. Methodological aspects of IT.

The typical visual IT testing session involves a subject being presented, at their own pace, with two lines, one substantially longer than the other, at a moderately brief duration. Immediately following the offset of these lines, a backward mask is presented. This prevents the stimulus image being held in visual iconic storage, and thus controls the speed at which the stimulus is seen by the subject. Subjects are then requested, in their own time, to say whether the longer of the two lines was to be found on the left or the right of the display. If the subject makes a correct run of discriminations at this duration, the exposure is reduced; otherwise it is increased to a level at which the subject can be more successful. In this manner a psychophysical curve unique to the individual is formed, tracing the ability to discriminate visually-masked stimuli from total to chance accuracy. ITs typically involve discovering the lowest duration at which the subject can achieve at a minimum of 85% discrimination accuracy. RT is not usually recorded in the course of IT testing, and emphasis is placed on the subject responding on the task accurately, rather than quickly.

The speed at which information can be taken in may be closer to the unitary, Galtonian physiological under-pinning of *g* than some arbitrary combination of RT tasks. As such, IT is being studied as an index of cognitive development (Wilson, 1984; Anderson, 1986; Anderson, 1988), and clinical impairment (Deary, 1989). Such research follows the reasoning that if IT is a measure of fluid *g*, then IT will follow the pattern that *gf* manifests in terms of cognitive development or impairment. Broadly speaking, this view finds support: IT increases with age up to about puberty, and appears to reduce with increasing age (Wilson, 1984; Charman, 1979). IT is particularly long in the mentally-handicapped (Nettelbeck, 1982; Hulme and Turnbull, 1983), and in those suffering from senile dementia (Brand, 1984).

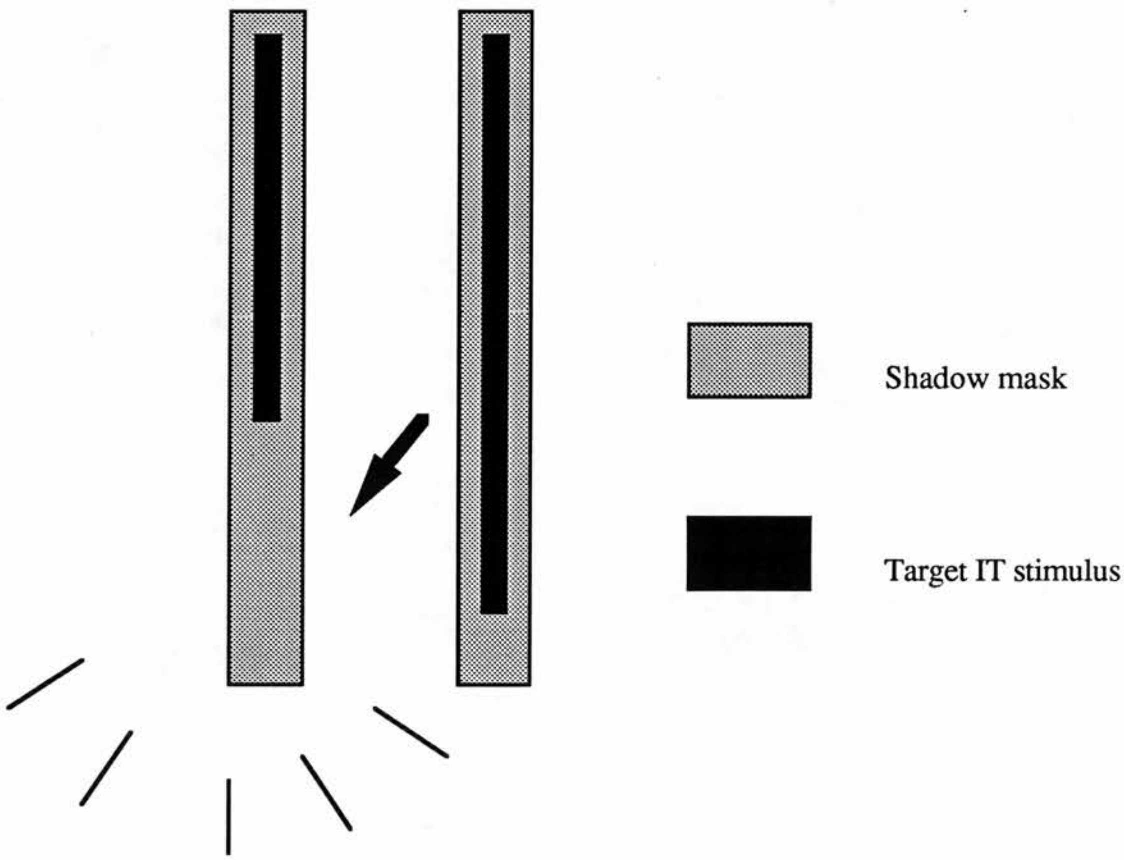
Early IT studies involved tachistoscopic presentations of the stimuli, with the pacing and control being based on the rate at which experimenters changed trials. Procedural modifications to the visual IT paradigm regarding self-pacing and automated psychophysical routines have been made following the computerisation of the task. Thus, Anderson (1986) tests children on an IT task resembling a 'Space Invaders' computer game, using a computer monitor screen to present the stimuli, and response keys to record the response. A number of studies now also show that a computer screen presentation does not entirely destroy the IT/IQ relationship, even when the studies are conducted with samples of University students (Longstreth, 1986; Deary, Caryl, Egan and Wight, 1989; Zhang, 1991). This suggests that the IT task is applicable outside the specialised equipment of the psychological laboratory. Furthermore, the IT/IQ relationship holds despite considerable variation in the experimental paradigm used.

1.6. Cognitive strategies and IT.

The possibility of a task that measures speed of perceptual intake being equally applicable to children, adults, minority groups and even the physically handicapped fits with the view that IT is a "transparently fair" task that may "attest the reality of *g* " (Brand and Deary, 1982). This notion was anticipated by Baron (1978), who said that "..in principle.. it is possible to find some simple, strategy- free task that can measure purported capacity and then show that groups differ in asymptotic performance on that task". However, and with precognition of the nature of this thesis, Baron added that "..there is no interesting individual difference not explicable in terms of strategy". This was not an idle *post-hoc* rationalisation; Nettelbeck (1982) reported that "in virtually all of our studies some subjects have been able to make use of other sources of information than the briefly exposed stimulus figure, such as subtle post- masking cues associated with apparent movement, and small changes in brightness". The phenomenology of this occurs when the IT stimulus figure is overwritten by the backward mask, and motion fills the side of the display where the shorter stimulus line was previously seen (see figure 1.6.i). Thus, for some subjects, IT appears not to measure mental speed alone.

1.7 Apparent motion.

Apparent motion is a complex phenomenon commonly experienced when one sees the moving images of a cartoon film; though the film is made of separate photographs, their rapid concurrent presentation makes the motion represented appear continuous. Rheinhardt-Rutland (1988) describes this illusory movement in a stationary stimulus as a product of adjacent movement. Apparent motion is seen in different viewing conditions, in a wide variety of displays, and occurs irrespective of display size. Whether the effect is based on stimulus or subject factors is dependent upon the task that initiated it. Petersik (1989) divides apparent motion into two distinct processes, one concerned with short-range processes, and one that occurred at a longer range. The short-range process reflects the activity of low-level, directionally selective motion detectors, and favours short stimulus durations. The long-range process reflects higher order perceptual activity, and favours longer stimulus durations. The short-range process is preattentive, unlike the long-range process, implying that the former involves a degree of parallel processing, unlike the slow , serial, attentive nature of the longer process (Dick, Vilman and Gagi, 1987).



The arrow indicates the apparent movement seen as the IT target stimulus is replaced by the shadow mask, giving the appearance of movement, flickering, and sometimes, brightness. This effect reverses side if the long line IT target is moved to the opposite side. Once the subject has become aware of this motion, they need only register the after-effect, then press the response key on the side opposite to the region of motion.

Figure 1.6.i. The nature of the apparent motion phenomenology reported by strategy users on an IT task.

Breitmeyer and Ritter (1986) note that short-range apparent motion effects are based on visual persistence, while long-range apparent motion effects are inhibited by visual persistence.

1.8 IT and apparent motion.

If a subject can perceive apparent motion cues, their IT may be artificially reduced, and IT may simply measure the efficiency with which they can apply an IT-penetrating strategy, rather than how quickly they take in simple perceptual information. In time, maybe, all subjects doing an IT task could develop this technique, whether by spontaneous development or another's instruction. In short, IT may be vulnerable to a performance strategy in which the subject watches for a flash, then reports that the target stimulus was on the side opposite. Self-reports from IT sessions (Mackenzie and Bingham, 1985; Mackenzie and Cumming, 1986; Brebner and Cooper, 1986) have confirmed that some subjects can make successful discriminations at very brief exposure durations through the use of apparent motion cues in the IT display. If the subject can identify the point at which the shorter stimulus line is overwritten by the backward mask, then the task of indicating which of the two lines presented was the longer is made simpler: the subject need only press the button contralateral to the motion. Amongst subjects who can use such information, the masking procedure fails to limit sensory input to the specified target durations, as backward masking actually provides additional information about the stimulus.

Two published studies have considered the systematic effect of apparent motion on IT (Mackenzie and Bingham, 1985; Mackenzie and Cumming, 1986). In each study a small sample of students was divided into those who reported using apparent motion effects in IT, and those who did not; in each case, they found the correlation between performance measures of IQ reduced to modest levels among subjects who reported using apparent motion cues (r = -0.20 for 16 subjects and r = -0.19 for 22 subjects respectively, both n.s.) . The correlation between IT and performance measures of IQ for subjects who did not report using these apparent motion cues was substantially higher (*r* = -0.72 for 13 subjects and *r* = -0.66 for 15 subjects respectively; both P<.01). The first of these studies gave the full WAIS (Wechsler, 1955) to the subjects, and discovered that, for non-strategy reporters, the IT/Performance IQ correlation was largely due to the significant associations between IT and the Block Design and Object Assembly subtests (*r* (13) = -0.76 and -0.75 respectively, both P<.009). The full sample correlations, close to the typical IT/IQ *r* described by Krantzler and Jensen (1989) were thus -0.50 and -0.45 (both P<.01). The IT/IQ correlation therefore broke down in groups of subjects who used apparent motion strategies, but remained for individuals who did IT by simply comparing the lines within the time available before they were masked. Does this mean that the correlation of IT and IQ is an artefact of combining strategy users and non-users into the same analysis, despite their doing the task in substantially different ways?

MacKenzie and Bingham (1985) found that about half of the sample naturally used a strategy based on apparent motion. Natural strategy users had a significantly shorter mean IT than non-users, although the two subgroups were not significantly different from one another on the WAIS or any of its subtests. This strategy could not be taught to the subjects; they could either use the strategy or they could not, irrespective of their measured IQ. The IT/IQ correlation obtained was not the result of differential strategy use by high- or low-IQ subjects, although the use of strategy produced lower mean IT than did non-use. Requiring non-users to apply the strategy resulted in a slower IT. This indicated qualitative, as well as quantitive, differences within a normal sample of subjects in the extent to which an effective strategy for performing an IT task can occur.

Mackenzie and Cumming (1986) extended this study in three ways; by using a culture-reduced IQ test (the Advanced Progressive Matrices; APM); by measuring the exposure duration at which subjects experienced apparent motion on the phi-phenomenon; and by looking at the effect that previous relevant experience (video-game playing) had on IT performance. Twenty-two of the 37 subjects indicated that they attended to apparent motion cues on the IT task, almost all of them reporting this cue within the first of the four IT trial blocks, the remainder reporting it in the second. The remaining 15 subjects attended to different cues, such as seeing a flash of light where the shorter of the two stimulus lines was previously presented, or watching for the discrepancy between between the lines in terms of the darkness outwith the stimulus lines. A correlation of -0.45 (P<.01) was found between IT and the APM for the full sample, this increasing to -0.66 (P<.01) when subjects who did not report an apparent motion strategy were analysed separately. There was no significant IT/IQ relationship amongst subjects reporting the motion cue. No difference was seen between motion-cue users and non-users on the APM, the speed at which they perceived apparent motion, or the reliability of their IT measurement. The difference between the two groups for IT was marginally significant (P<.07), but considerably more variable (P<.01). No evidence was found that playing video games led either to briefer ITs, or was initially more popular among those subjects with faster ITs.

These studies showed that IT and IQ are correlated highly, even within a high-IQ population, and that this relationship is stronger if subjects who report motion-cues are excluded from the analysis. For some subjects, IT may measure some mental process or capacity that is strongly related to individual differences in intellectual level. However, this does not seem to be the case amongst those who use apparent motion cues. Differential use of these cues may explain why the IT/IQ relationship has ranged from -0.92 (Nettelbeck and Lally, 1976) to -.17 (Irwin, 1984). What defines a subject as a potential motion-cue user was not provided by the results of Mackenzie and Cumming's study, though it replicated the IT/IQ correlation. Their article concluded "..the explanation of why the measure is strongly related to intellectual level in some subjects but not in others may properly be considered the first problem for that research."

The effect of strategy on IT is not so surprising if one takes an alternative view of *g*, in which multiple processes are considered. This perspective is rather more theoretical,and takes within itself the tradition of American cognitive psychology, and even artificial intelligence. The approach became crystallised with the publication of Miller, Gallanter and Pribram's "Plans and the Structure of Behaviour" (1956), in which complex mental processes were described formally, with each subprocess itself being defined precisely, in the same manner that one writes a computer program - a popular, if debatable view.

1.9 Sampling and Multiple-process theories of Intelligence.

One of the earliest multifactor theories of *g* was that of Thorndike (1927), who proposed that human abilities consist of multiple bonds or neural connections acquired through experience, and that successful performance on various tasks involves different but overlapping 'samples' of the infinity of bonds that constitute intelligence. It was Thorndike's view that individuals differed innately in the potential number of bonds they could acquire, this being defined by the constraints placed on the neural elements involved. The theory did not stipulate any structure or organisation within the bonds. Thompson (1947) refined this theory, and argued that the correlations between tests were an index of the proportion of elements commonly sampled by the tests involved. He argued that *g* and specificity derived from factor analysis of a number of tests that again contained different but overlapping samples of elements. Any factors derived are not true cognitive elements, as the mind has the potential to link any construct with another. Factorial structure and organisation are thus artefactual to tests that sample large or small numbers of bonds and elements. The more elements the test samples, the more the test will correlate with other tests. Regularities in factors are a product of the statistical distributions the elements and bonds show amongst themselves.

This was not the most empirical of models; Loevinger (1951) felt that, until Thompson provided a clear statement of what would confirm or refute the theory, it should not be considered as a scientific statement. However, a reading of psychology will show that such considerations rarely stop opinions being taken as facts. So it was with sampling theory, which, in a modern formulation, now sees *g* as the product of an individual's skills, knowledge, and problem-solving strategies at a given time (Humphreys, 1984). *g* is now attributed to individual differences in the number of cognitive skills generalizable across a number of problem-solving situations.

A more sophisticated refinement of sampling theory to be found in the component-process theory of *g*, which at least provides a structure to test. Robert Sternberg's theories stipulate a finite number of elementary information-processing components, each definable in terms of the function they perform. According to this theory, *g* is due to the conscious execution of general components of information-processing. *g* has an executive role over mental processes, in which conscious processes, feedback from specific mental processes, and their context-relevance is continuously upgraded.

This model has expanded to consider aspects of intelligence beyond the laboratory, the psychometric test; or even IQ, and is known as the triarchic theory of intelligence (Sternberg, 1984, 1985). The model has three subtheories, which attempt to define and measure human intelligence, differentiating between cultural and universal aspects of intelligence.

1.10 Sternberg's Triarchic Theory of Intelligence.

The first subtheory is **contextual**, and emphasises the cultural environment the individual finds themself; in this scenario intelligence involves "the purposive adaptation to, shaping of, and selection of real-world environments relevant to one's life" (Sternberg, 1984). Intelligent performance is thus placed firmly in an everyday context, and is not to be considered simply as a measure of academic success. This subtheory could equally be seen as an acknowledgement that personality colours how intelligence is expressed. There are two other subtheories, which are presumed to hold universal components of human intelligence.

The second theory is **two-facet**; its basic assumption is that a task to measure intelligence requires either the ability to deal with novel demands, or the ability to automatise information-processing. Most problem-solving, at least at the beginning, involves novelty, which presently becomes automatised. Implicit within this subtheory is the continuum of conscious to unconscious processing, and the rate at which an individual acquires skills. Sternberg suggests that controlled processing, which requires effort and attention in order to select appropriate cognitive operations, then sequence, perform, and monitor them (with appropriate modifications via feedback processes) is unsurprisingly slow and deliberate - until the process becomes automatised (Sternberg, 1984). Sternberg suggests that the rate at which an individual can automatise a performance, or can respond to a novel problem, may be a marker of their intelligence.

The contextual and two-factor aspects of this theory are driven by the **componential** subtheory. A component is a basic or elementary information process that operates on internal representations of objects or symbols. All thought is composed of such symbolic processing, irrespective of the cognitive task. Performance components represent the basic operations involved in any cognitive act. Thus, in the case of analogical problems, performance components would involve encoding, comparison, and responding when determining the relationships between and among stimuli. When component processes are executed in the correct order an individual can solve a problem correctly. Thus, providing we can understand the correct order of components, and their optimal sequencing, the rules of intelligent, symbolic thought can be understood.

Organising the performance components requires a high level control process. Sternberg describes the control process as a parallel system of **metacomponents** 'bootstrapping' one another, these metacomponents taking the role that the 'central executive' or 'homunculus' would have taken in earlier psychological theories. Metacomponents plan, monitor and make decisions concerned with the execution of tasks. They also decide what the problem is; what it needs to be solved; select the appropriate performance components; select the information representation suitable for the performance component; select a strategy for combining and sequencing performance components; allocate resources to executing the process; monitor the solution of the problem; and respond to external feedback.

A demonstration of metacomponents involved in cognitive performance is seen in a study by MacLeod, Hunt and Matthews (1978), who looked at differences in subject strategy on the semantic-verification task (Clark and Chase, 1972). The semantic-verification task involves subjects being presented with a sentence that relates to a picture presented subsequently. For example, the sentence could say "Star is left of plus", with the picture being "* +". Sometimes the sentence and picture do not correspond. The subject is presented with an even number of truthful and non-truthful sentence-picture pairs, with the time taken for the subject to decide whether the sentence is true or false being recorded. MacLeod *et al* (1978) found that individuals differed in the strategies they used to perform the task. High- spatial subjects tended to use visualisation strategies, where they converted the sentence given into a picture, then matched this to the picture shown. High-verbal subjects did the converse, converting the picture into a sentence. The two groups showed different patterns and profiles of performance, and appear to have chosen the form of representation best suited to themselves. The results of the experiment emphasised that individuals differ in how quickly and efficiently they execute components, and also how they perform (and self- monitor) their progress in solving a problem. Thus, when analysing cognitive performance, one should look at the nature of the components (and metacomponents) used to direct the more basic processes.

Sternberg (1984) also considers knowledge acquisition components; these are processes used in gaining new declarative or procedural knowledge. Such components include the selective encoding, selective combination, and selective comparison of information. Presumably this is because learning involves using premises that are understood to understand those which are not, and because the first premises must be disregarded in order to assimilate the new information. By understanding the the rules of knowledge acquisition, it is argued, the practical aspects of real-world intelligence can be refined. One such example of practical, real-world intelligence is, of course, the successful placing of bets on horses at the racetrack, which Ceci and Liker (1986) argue, demonstrates the importance of knowledge components over intelligence, or information-processing speed.

1.11. Sternberg's model in relation to the speed theory of intelligence. According to the triarchic theory of intelligence, the extent to which existing IQ tests measure intelligence and predict real-world performance is the extent to which both tasks measure metacomponents (Sternberg, 1980). Aspects of metacompotential activity - sensitive to feedback, problem elucidation, task selection and organisation, monitoring solution processes - are all crucial to test and task performance. This also holds for those tests linking speed of processing to intelligence, to the extent that experimental measures measure cognitive speed to begin with. Thus, Sternberg has remarked that "except on stripped-down laboratory tasks, 'hasty judgements' are not always intelligent ones. If we want to understand what makes judgements intelligent ones, we need to go beyond studying their haste" (Sternberg, 1986). In the more popular context of "Psychology Today", Sternberg remarked that "A big thing in IQ testing is speed, but almost everyone regrets some decision that was made too fast" (Trotter,1986). These are wise words, but hardly new; Thurstone (1924) proposed that a critical element of intelligent performance is the ability to withhold rapid, instinctive responses, and to substitute for them more rational, thought-out responses.

Sternberg's substantial disagreement with the speed theory of intelligence is spelt out in his rejoinder to Vernon (Sternberg, 1986a). He has a number of objections. Speed is only one variable. The emphasis placed on speed detracts from the quality of an individual's thought. The correlations between speed and IQ do not indicate speed causes higher IQ. Experimental speed tasks are ecologically invalid, and confuse maximal and average performance. Subjects may lack motivation on trivial tasks. The speed of the processes involved is missed in gross reaction-time measures. Experimental measures of speed are unfair to subjects, because slowness of thought normally reduces errors, bad decisions, and errors of impulsivity, and whether one responds quickly or slowly generally depends on the task concerned (Sternberg, 1986a). The correlation between simple cognitive tasks and IQ is an artefact of the fact that both tasks are timed. The emphasis on speed is a gross over-generalisation, as speed may account for IQ in some people, and for some mental operations, but it does not hold for all people, or for all mental operations. What is critical is not speed *per se*, but rather speed selection - knowing when to function rapidly or slowly - according to task or situational demands. Resource allocation, in addition to the resource itself, is central to general intelligence (Sternberg, 1985).

Sternberg argues that even the simplest of cognitive tasks involve metacomponents. Thus, the correlation between RT and IQ increasing with choice- alternatives (Jensen, 1982) is attributable to the increasing amount of metacomponential decision-making involved. The same follows with other RT-type tasks, as the RT/IQ correlation increases with the increasing complexity of the RT task. High-level decision processes contribute to the correlations observed between such tasks and IQ, not simply speed. In addition, repetitive (but trivial) tasks become automatised over a large number of trials, and so measure the efficiency of automatization processes. Few of these objections have been empirically tested.

Much is assumed by the strategic theory of intelligence; that introspection is accurate; that an understanding of how one approaches, and revises problem-solution provides a way of controlling mental operations; and that mental operations are modifiable through reason. Some of the assumptions of declarative strategic theories such as Sternberg's are due to the cross-fertilisation of ideas between artificial intelligence and modern cognitive psychology. According to this approach, to understand *really* intelligent human behaviour, for example solving equations, or playing chess, you ask people (preferably experts) to introspect how they do these tasks, which are then formally expressed, and converted into effective computer programs. If you can teach the abstract principles of these problem-solving models to ordinary people, you can improve their intelligence (Newell and Simon, 1972).

But is intelligence so easy to simulate? The correspondence between formal models and people is by no means perfect. The trivial things that humans find easy - seeing, moving in three-dimensional space, understanding people with poor diction, comprehending doctor's handwriting - are the very things we cannot formally explain. The best computers, using the most ingeniously-programmed software still have difficulty understanding the spoken word. Our fundamental ability to perceive patterns, extract features, and integrate our senses generally makes even the most apparently dull human more intelligent than the finest computer. It may be that in the humdrum operations that make humans what Robert Fripp once described as 'small, mobile, semi-intelligent units' resides the mystery of our intelligence. If this is true, strategic theories are castles built on sand.

1.12 Testing strategic theories with IT.

That there are apparent motion effects within IT tasks is not simply a matter of reduced or over-inflated correlations with IQ. Given the systematic effect of introspected use of strategies on IT, it is possible to examine directly some of the claims made on behalf of strategic theories regarding intelligent performance. One such prediction would be that strategies are teachable. This may be true for high level intellectual problems, but it is not the case for IT: Mackenzie and Bingham (1985) found that they could not teach subjects to use apparent motion cues. When individuals were told to use these cues, they showed a significant reduction in performance. A further study tested another possibility derived from general strategy theory; that a comparable real-world task (playing a computer game) positively transfers with some general (but unspecified) advantage to a computer-presented IT task. There was no difference in IT performance, irrespective of whether subjects regularly played video-games or not. In neither study was another general strategic prediction supported: that individuals who report performance strategies on experimental tasks are more intelligent than those who do not report apparent motion.

1.13 Intentions of this thesis.

The popularity of the strategic theory of intelligence may be expressed by pointing out that in the 1000-plus pages of "The Handbook of Human Intelligence" (Sternberg, 1982), little mention is made of speed theories of intelligence. Introductory textbooks of psychology in 1990 are no better. However, the claims of the speed theory are equally emphatic, and Brand (1987) has challenged strategy theorists to commit themselves to empirically testable hypotheses concerning the performance of strategy-users on simple cognitive tasks such as RT or IT.

This thesis is an attempt to pit strategic and speed theories against one another, using the strategy-vulnerable IT task as the dependent variable, and self-reported strategy-use and measured IQ as independent variables. The use of strategic data will depend on verbal reports; a procedure that requires that the introspection is a product of the basic process being examined in the first place (Ericsson and Simon, 1980). Introspection is not without methodological problems, but it is difficult to imagine how one could know the content of another's thought in any other way. These results will be supported by performance measures from the IT task, hopefully following Karl Lashley's advice that "..introspection may make the preliminary survey, but it must be followed by the chain and transit of objective measurement" (Lashley, 1923). By a series of experimental manipulations of IT concerned with strategy generalization, stimulus ambiguity and false feedback, concurrent-task performance, and response latency, the nature of the specific strategy used on IT, and the general claims of strategy theorists will be considered experimentally.

Chapter Two

How general is the effect of strategy on Inspection Time tasks?

2.1.1. Introduction.

Strategic accounts of intelligence attempt to explain individual differences in *g* by reference to a hierarchy of strategic processes. These processes are sometimes said to be used by individuals to varying extents, and with differing degrees of effectiveness. At the pinnacle of this structure are 'metastrategies', conscious strategies of using strategies (see figure 2.1.i). Differences between individuals in intellectual level are said to be largely due to these metastrategic processes: higher-IQ individuals may be thought to have greater insight into (and command over), the other conscious problem-solving processes of their minds. Using this reasoning, it is possible to argue that individual differences in problem-solution are mainly due to the different strategies that subjects apply (Hunt, 1980; Sternberg, 1981). Tests of fluid *g* (*g*f), often involve testing non-verbal visuo-spatial problems using non-entrenched (i.e. novel) tasks. The processes required for overall problem solution are assumed to be at a high level in the hierarchy: individuals must, for example, match patterns involving several different components to solve items from the Raven's Matrices. Performance on IQ tests therefore requires subjects to use concepts or form strategies that differ in kind from those which they are used to (Sternberg, 1980).

An alternative contention is that *g* f can be measured by measures of basic information-processing speed. One such task involves estimating the speed of perceptual intake, using an Inspection Time (IT) paradigm (see chapter 1). Is it the case that 'novel' laboratory tasks to assess the speed of basic information-processing function (supposedly measuring intelligence at a "biological" level), confuse the

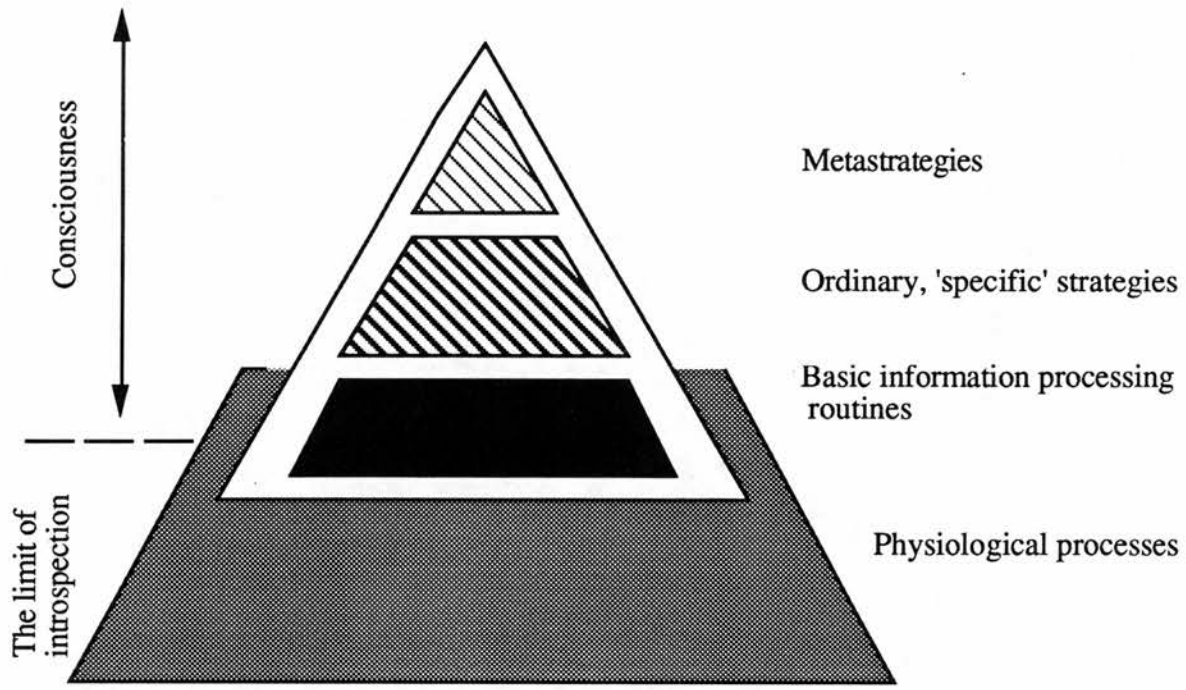


Figure 2.1.i. The hierarchy of processes leading to intelligent behaviour.

direction of causality? Rather than intelligent individuals having some innate advantage in the speed of their mental processes, is this apparent speed advantage, in truth, a product of the specific and general strategies that more intelligent individuals bring to any task they are presented with?

This is not a recent idea; in a letter to Charles Spearman, dated 1904, E.L. Thorndike wrote:

> "As I understand you now, your view is that if we got an accurate measure of the common element in all varieties of sense discrimination, it would correlate perfectly with intelligence, the fact being that the different varieties of sensory activity agree together only in a general core or kernel of intellect itself. If this were the case, I should interpret it as follows: that in measuring any sensory activity we measured a complex of the mere sensory capacity and of the capacity to understand instructions, to be attentive and ambitious, to use all the clues that might be available in making the sensory judgements." (in Joynson, 1989.)

Thorndike's view was that 'mere sensory capacities', independent though they generally are, may not be measurable without interference from cognitive and motivational processes. The view that a correlation between IT and IQ could be due to the more efficient IT strategies of higher-IQ subjects (rather than a high-IQ advantage in passive and unconscious information-processing), is thus as old as the idea of *g* itself.

This study addresses the degree to which strategic processes during IT tasks are general to all tasks, or specific to particular versions of IT. It also enquires whether the strategies observed correspond in any coherent way to the IQs of the subjects tested. If it was found that there was a specific strategy associated with IT, it would make sense for subsequent studies to address that strategy in particular; if metastrategies drive performance on IT, and are seen in subjects with higher intelligence, then we can devote ourselves to programmes of teaching thinking skills (Blackman and Lin, 1984).

However, if strategies are irrelevant to performance on the IT task, and intelligence is strongly associated with perceptual intake speed, then drugs to speed the physiological processes underpinning this process could possibly help raise IQ - a proposition with considerable value for the mentally handicapped, or those with dementia (d'Elia, Frederiksen and Bengksson, 1985).

2.1.2. General strategies.

General strategies for intelligent performance involve organised mental processes at a high, sometimes introspectable cognitive level (Baron,1978; Campione and Brown, 1978). The conscious attention given to a problem represents a form of "mental self-government" (Sternberg, 1986b). Sternberg's analogy exemplifies the executive role of intelligence, driving our actions in a way that is organised, coherent and responsive both to our internal needs and to those requirements imposed upon us by the environment. This analogy is possibly true; unfortunately, democratic and planned states can promise the world, and be, in truth largely top-heavy systems that achieve less than they profess. Strategic theories of intelligence have sometimes seemed analogous: by having the central executive promise so much, they appear to deliver little.

The general strategy approach emphasises the idea that apparent differences in 'intelligence' and allied abilities arise from differential use of metastrategies and metacomponents. Thus, Campione, Brown, and Ferrara (1982) describe metacomponents as "the components that emerge without instruction in the intellectually average and above average but .. require explicit instruction for those of below-average ability" (Campione, Brown, and Ferrara, 1982). General strategy theory has some face validity in that one sometimes needs a cautious and considered response to intellectual problems: neither chess problems or decommissioning nuclear power stations benefit from quick decisions. Metacognitive viewpoints emphasise the self-knowledge one has regarding one's cognitive state and one's mental processes (Flavell, 1978), and are defined by the function they perform; general skills that can be applied to a wide variety of situations (Campione, Nitsch, Bray, and Brown, 1982).

Metacomponents are allegedly responsible for the initial decision to be strategic; and this general strategic knowledge apparently produces an understanding by individuals that their performance improves, provided that sufficient effort is put into strategy selection and deployment. Metacognition thus directs the conscious use of such strategies, monitors them, and enables their adjustment as necessary. For example, the motivational correlates of metastrategy, such as self-esteem, internal locus of control, and constructive attributions regarding the cause of success or failure (Belmont and Mitchell, 1987), are of considerable importance when encouraging better educational performance in underachievers. Strategy use is never spontaneous, but the result of continuous, long-term developmental processes reflecting the maturation of the metacognitive system; automatization of strategies is attributable to prolonged strategy use combined with extended metacognitive development (Borkowski, Carr and Pressley, 1987).

As might be apparent, most allusion to strategies is conceptual, and describes possible sequences of behaviour within a particular problem, rather than behaviour specific to an experimental situation. However there have been exceptions, and in the process of understanding the limitations of the IT paradigm, two possible types of strategy have been discussed; specific and general strategies.

2.1.3. Specific strategic accounts of performance on IT tasks.

Researchers of IT have acknowledged the possible vulnerability the task has to cognitive strategies; Nettelbeck (1987) and Brand (1984) have both discussed the problem of apparent-motion with visual IT tasks that involve the subject discriminating the shorter of two briefly exposed lines. Following the backward masking of the stimulus, some subjects report seeing a flicker contralateral to the target side of the display. This flicker is at the point where the empty area beneath the short target line (an area of brightness) is covered by the dark mask, and could be likened to that experienced when one views a scene under stroboscopic illumination. Some subjects claim to use this phenomenology exclusively when presented with visual IT stimuli otherwise too brief to discriminate (see sections 1.6 to 1.8 of the introductory chapter).

2.1.4. General strategic accounts of performance on IT.

Mackintosh (1986) is willing to grant a modest negative correlation between IQ and IT, and that some small aspect of IQ involves mental speed, itself measured by IT; however he suggests that these small correlations are equally explicable by differences between subjects of attention or sustained concentration. As all tasks require the subject to attend to the stimuli presented prior to some response, and attention is, to a degree consciously directed, "attention" could be said to be a general strategy.

A vaguer set of criticisms regarding IT derives from Howe (Howe, 1989a; 1989b). Howe's preferred explanation for the IT-IQ phenomena involves personal attributes that affect performance on a number of tasks. These include competitiveness, self-confidence, attentiveness, persistence, and the degree of enthusiasm the individual has for being tested. Notable by absence from this list of critical attributes for investigation are any personality traits quantifiable by recognised tests. According to Howe, even with very simple tasks using familiar materials, performance on tasks is affected by experience-induced factors that (individually or combined), could account for the observed correlations. He adds that however simple or familiar the task, it is unlikely that the qualities they draw on are 'basic'.

The observed correlations (small as Howe estimates them to be) between information processing tasks and global measures of ability need not reflect inherent mental processes; they could be equally seen, at least in part, as products of an individual's particular experience (Howe, 1988; 1989a).

2.1.5. Auditory IT.

It is not possible to envisage a specific strategy equally useful across sensory domains. However, by presenting IT in an auditory modality (AIT), one can investigate the variety of general strategies applied across different types of IT task. Though visual IT tasks sometimes produce movement artefacts in the process of their masking, auditory tasks may provide a less strategy-vulnerable methodology for measuring perceptual intake speed. AIT has been used to assess whether the IT phenomena is specific to one sensory modality, or general to the processing of information (Deary, 1980). Though this study found that AIT correlated with Raven's Progressive Matrices (RPM) at -0.70, and at -0.66 with Mill Hill Verbal (MHV) test scores, it only involved 13 subjects. Subsequent, larger studies have found that the correlation between AIT and IQ is rather lower; Irwin *et al* (1984) found the correlation (r) between AIT and the SPM and MHV for 50 schoolchildren to be -0.23 ($P<.05$) and -0.32 ($P<.01$) respectively; and Nettelbeck, Edwards and Vreugdenhil (1986) found an r of -0.38 ($P<.05$) between AIT and the Advanced Progressive Matrices for a cohort of 30 students; AIT correlated at 0.39 ($P<.05$) with a VIT task.

One criticism of the AIT task has been that when AIT stimuli are presented to subjects at short durations, the frequency spectra of the stimulus tones overlap, preventing perceptual discriminations of pitch (Irwin *et al*, 1984). Irwin observed a correlation of -0.51 ($P<.02$) between AIT and a measure of pitch perception, and advanced the possibility that AIT was as much a test of pitch discrimination as temporal resolution. (Raz, Willerman and Yama (1987) found that the Cattell Culture-Fair measure of *g* correlated at between -0.42 and -0.54 with measures of frequency resolution in for 25 University students; resolving a stimulus, it is advanced, may be important in the determination of an optimal IT.) A recent study by Deary, Head, and Egan (1989) addressed this problem; AIT, pitch perception and ability tests were given to students in the same test battery. For the 34 subjects able to perceive pitch accurately, AIT and the AH6 correlated at -0.39 ($P<.01$); when the pitch perception measure was partialled-out, the correlation reduced to -0.38. Thus the association of AIT and IQ was not attributable to differences in pitch perception between subjects for this study. (This study also found that about 40% of the subject pool were 'tone-deaf'. This suggests that just as subjects in VIT studies should have corrected vision and screening for normal visual acuity, so should prospective AIT subjects be given an initial test of pitch perception.)

The AIT paradigm enables one to investigate perceptual intake speed without problems of poor masking, and this in turn means that the strategies employed in such a task would have to be of a very general kind, as it is difficult to imagine a specific strategy equally applicable across radically different tasks of perceptual discrimination. Better scores on the tasks may arise however because some people are more generally attentive, vigilant, motivated or organised in their approach to IT tasks.

2.1.6. Do strategies and speed complement one another on IT tasks?

There is a third, compromise position. This is that combining strategy and processing speed inflates the speed differential between low and high IQ individuals. The simplest interpretation of intelligence and speed of information-processing processing studies has been to suggest individuals differ in terms of some global advantage ('speed', or 'attention') that affects their entire cognitive system, for example a faster or more efficient central nervous system. However a multiple factor theory may equally well explain overall function; individuals may differ on particular special abilities, and these may interact with specific processing advantages. The overall level of general ability might determine the rate at which local subsystems can be acquired, and so determine their number; optimal ability may also determine the optimal level of efficiency within one of these sub-systems (Rabbitt, 1988).

If individuals can learn special purpose productions based on procedural knowledge (e.g. how to act strategically during experimental tasks), basic performance may be supplemented by these productions, and consequently lead to exceptional performance on particular tasks. The observed degree of transfer from one learned production to another may depend on the nature of the tasks being compared. One testable prediction from this abstract possibility will be examined by the forthcoming study; that individuals who combine high IQ and strategy reporting will have faster AITs as a group, than individuals with no such characteristics.

2.1.7. Intentions of the present study.

Though psychophysical and psychometric techniques are undoubtedly adequate for assessing perception and intelligence, their ability to investigate phenomenological aspects of experimental tasks are limited; in addition, strategic theories are often phrased in generalised ways that are difficult to operationalise.

The most practical solution to this problem is to select a criterion group; an allegedly metastrategy-saturated sample in whom passable levels of motivation, planning, mental speed and intelligence co-exist; undergraduate students. The current study uses three variants of IT; two visual tasks (VIT, LIT), and AIT, all of which have been previously found to correlate with each other, and with measures of IQ in student populations (Deary, Caryl, Egan and Wight, 1989).) AIT is of interest in that it is unclear whether there is any applicable strategy involved beyond paying attention to the stimuli. LIT is a visual IT task that uses alphanumeric characters on a computer monitor and is supposedly strategy-free (Longstreth *et al*, 1986). The VIT task has an established strategy associated with it; some individuals report observing an apparent-motion effect that they effectively use to guide their discriminations. Others miss this phenomena, and when informed of the relevant performance strategy, are still unable to apply it (Mackenzie and Bingham, 1985).

The present study measures IT and IQ, along with phenomenological reports regarding how the subjects completed the IT tasks. These introspections will provide the basis for a sub-analysis of IT performance by strategy type.

Predictions regarding the likely outcome of this investigation vary according to the emphasis one places on strategy as the explanatory variable in the IT phenomena. Given a range of IT tasks and IQ measures, those who emphasise the primary role of some kind of 'mental speed' would expect:

1a. The IT tasks to positively correlate with each other.

1b. The IT measures to correlate negatively with measures of IQ.

1c.The various subjective introspections regarding how the IT tasks were done to be irrelevant (and subsequently show no significant effects).

Those who suspect general strategies to be the basis of the IT phenomena would make different predictions:

2a. Tasks would correlate better in groups containing a mixture of strategy-using and non-strategy-using subjects. (Because strategy users would be good at all tasks, yielding positive correlations between the IT tasks for mixed groups of strategy users and non-users.)

2b. Individuals who report strategies would be of higher IQ than those who did not.

2c. The most effective strategies would be adopted by the most intelligent subjects.

3. A subsidiary hypothesis would suggest a greater incidence of strategy reporting in higher-IQ subjects with briefer auditory IT. This would be because higher IQ combined with faster intake speed frees thought for strategic ploys in other conditions.

2.2. Method

.2.2.1. Design.

The experiment followed an independent-subjects design in which subjects were allocated *post-hoc* to strategic conditions according to their introspected self-reported strategies, and was otherwise a replication of the study conducted by Deary, Caryl, Egan, and Wight (1989). The dependent variables (strategy, AIT, LIT, and VIT, scores on the Alice Heim 5 (AH5)) are described below.

2.2.2. Subjects.

Forty one subjects were derived from an undergraduate practical in differential psychology. They all had normal (or corrected to normal) vision, and were pre-tested prior to AIT with the Bentley Pitch Perception task (Bentley, 1966) to ensure they had adequate pitch discrimination for the AIT task.

The motivation and expectations of subjects was not directly recorded; but given the regular practical classes attended, and the voluntary choice given in selecting a Psychology degree, willingness to participate in the study could be reasonably granted. As with most other practical classes, the procedure of the experiment was discussed prior to its running, with the theory and methodology being explained after the data had been collected.

2.2.3. Experimental tasks.

2.2.3.1. AIT.

The AIT task followed the paradigm developed by Deary *et al* (1989); stimuli were given at a fixed pace, using a method of constant stimulus differences; stimuli were square wave tones produced with an XR320 monolithic timing circuit. Stimulus tones were of a clearly dichotomous nature, 880 and 784 Hz, and were correspondingly high and low-pitched; these were backwardly masked using a warble of both tones. The stimuli were presented by a tape recorder through headphones. Each trial involved a cue tone prior to stimulus pairs of low-high or high-low tones, each presented for identical durations, followed by a 1 second warble mask. In the inter-trial period the subject ticked either a high-low or low-high box on a response sheet. This indicated the order in which the subject thought the two tones had been played at the commencement of the warble.

Subjects were given two practice blocks of 10 trials each, with stimuli for this condition being presented at 200 msec durations. The experimental task was composed of 13 blocks of 10 stimulus pairs presented in decreasing durations - 200, 150, 125, 100, 85, 70, 55, 40, 30, 20, 15, 10, and 6 msec. Subjects were excluded from the task if they achieved less than 90% accuracy in the practice trials, on the assumption that poor performance at this level demonstrated an inability to discriminate pitch.

2.2.3.2. The visual IT tasks.

Both visual IT tasks were presented on the screen of a computer monitor; both used the PEST algorithm (Taylor and Creelman, 1967) to derive a psychophysical threshold, and both involved the subject pressing, in their own time, a response key. Both tasks gave subjects a rest every 10 trials, with a "well done" message if eight (or more) of the previous 10 trials were correctly discriminated. If less than eight had been discriminated correctly, the rest screen read "Please pay attention".

2.2.3.3. The PEST algorithm.

PEST involves subjects being presented with stimuli at 200 millisecond exposures, and a step-size of 75 milliseconds; for each block of 5 trials at a particular duration correctly discriminated, the exposure duration of the stimuli was reduced by 75 milliseconds. Each time the subject made a reversal of direction (as would follow making two errors at a given exposure speed), or an improvement following the lengthening of the exposure speed, the step-size was halved. This adaptive-staircase procedure continues until the step-size is 1, and the subject is performing with at least 85% accuracy. By virtue of the algorithm adjusting to the best performance of the subject, redundant investigations of durations at which the subject would discriminate at either 100% or chance levels are minimised.

2.2.3.4. LIT.

The LIT task presented subjects with either a squared rectangle 8mm by 6mm, or a diagonal backslash about 1 cm long, with the fixation point and mask being identical; a combination of both stimuli presented simultaneously at the same point on the screen.

The phenomenology was of being presented with either an "O" or "/" symbol first, this being followed by the other symbol, then both being masked by a zero ("0"). The experimental response involved the subject deciding which of the two stimuli was presented first. If the diagonal target line had been presented, the subject pressed the "/" (backslash) key of the computer terminal; if "0", the subject pressed the "z" key.

2.2.3.5. VIT.

The VIT task was a standard visual IT task involving two vertical lines, one a third shorter than the other, presented for a brief duration, this being followed by a backward mask. The backward mask was composed of two thicker lines that completely overlaid the target lines, with the mask being used as a fixation point prior to the stimulus display. Responses were made through either the "z" or "/" key, according to whether the target long-line stimulus had been presented to the left or right on the monitor (see figure 2.2.i. for an example of the VIT and LIT stimuli).

2.2.4. Psychometric tests.

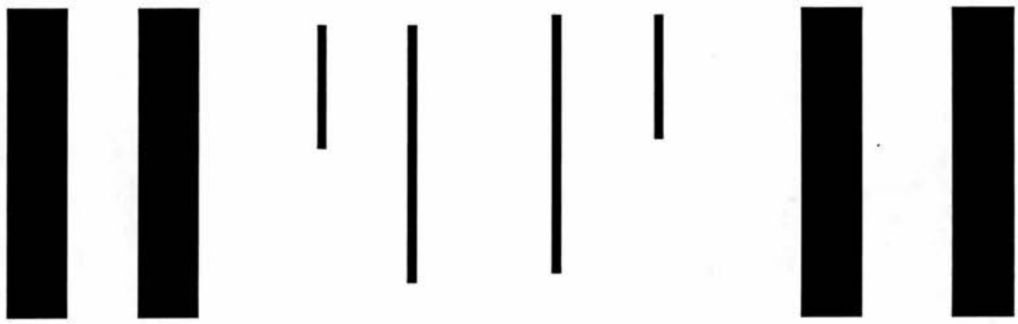
2.2.4.a. **The Bentley Pitch Perception Test** (BPP; Bentley, 1966).

The BPP is a subtest of the Bentley test of musical ability, and measures pitch discrimination. Subjects are presented with 20 unmasked tone-pairs of about 0.5 seconds each. Each trial presents tones that are higher, lower, or the same in pitch, and the subject must decide whether the second tone is identical to the first.

2.2.4.b. The **AH5** (Heim, 1968).

The AH5 is a test of ability developed for use with higher ability groups. It has two scales, one verbal (AH5A), one non-verbal (AH5B). Even in college student samples, the two scales typically correlate at about 0.70. The total score (AH5C) gives an overall estimate of the individual's general intellectual ability.

a) VIT task.



b) LIT task.

Either Or

1. Fixation point 2. Target stimulus 3. Masking stimulus

Figure 2.2.i. Stimuli for IT task presented using a computer monitor.

2.2.5. Strategy Elicitation.

Between the AIT and VIT tasks, subjects were asked to report any strategy they used on the IT tasks, being specifically invited to "Please write down the way that you would tell a friend to do the IT tests". This technique was used to elicit performance strategies from IT tasks by Brebner and Cooper (1986). Due to the extended and repetitious nature of the AIT task, it was felt that the only appropriate strategy possible would be to pay attention to it. The LIT task was administered last, and because many of the subjects had other lectures, or wanted to leave the practical class, it was found impractical to ask for introspections at the end of the testing session.

2.2.6. Procedure.

The entire class completed the AH5, and was then divided into two groups. Both groups did the IT tasks in the same order, VIT followed by LIT. Each subject sat in a small cubicle equipped with a computer and monitor, a headphone socket (with headphones plugged in), a small loudspeaker, and two record forms (for strategy elicitation, and AIT). AIT was the first investigation, and was at a fixed pace, this being set by the AIT recording described above. The total time for this procedure was about 20 minutes. The subsequent IT tasks were both presented on the computer monitor, were self-paced, and followed the PEST algorithm, so adjusting to the individual's optimal performance.

As the IT tasks were being administered to a number of individuals simultaneously, the experimenter could not supervise each individual's response exclusively. Thus, the programs used had a number of features to minimise procedural difficulties such as over-impulsive (or inappropriate) responses. The program emphasised that the task did not involve reaction time, and that one could take as much time over their decision as necessary. For the duration of the two visual IT tasks, the only keys on the computer terminal able to take a response were those programmed to, the remainder being disabled. A response was not accepted until the mask had been presented, discouraging over-hasty decisions. A rest period was given every ten trials, enabling subjects to have a break from the task. At the end of each visual IT task, the computer produced a brief "bleep" and printed the estimated IT (with the number of trials need to derive it) on the screen of the monitor. In the period between the VIT and LIT tasks, subjects were asked to complete their strategy elicitation record. Following the completion of LIT, subjects left the practical class. The nature of the study was explained to them in the practical the following week.

2.3. Results.

2.3.1. Results for the full sample.

Forty one subjects completed the experimental procedure. A summary of the means, standard deviations, and their inter-correlations can be seen at table 2.3.1. AIT, VIT, LIT and AH5 scores were not significantly different from those previously reported for samples of undergraduates (Deary *et al*, 1989).

Table 2.3.1. Means, SDs, and correlations between variables (n = 41).

	VIT	LIT	BPP	AH5A	AH5B	AH5C	Mean	SD
AIT	26	04	-04	12	24	21	83.8	36.6
VIT		29 *	-23	-15	-22	-21	41.0	24.0
LIT			17	-27 *	-41 **	-39 **	38.7	43.9
BPP				17	-02	09	17.6	1.4
AH5A					52 ***	87 ***	15.8	4.1
AH5B						87 ***	19.4	4.1
AH5C							35.2	7.1

(All decimal points dropped, one-tailed test. Significance ; * = $P<.05$; ** = $P<.01$; *** = $P<.001$.)

The first speed hypothesis (1a) predicted that the different IT tasks would correlate with one each other. The visual tasks correlated slightly, but the visual IT tasks did not significantly correlate with AIT (AIT/VIT r = 0.26, n.s.; VIT/LIT r = 0.29, P<.05; AIT/LIT r = 0.04, n.s.). The second speed hypothesis (1b) considered the correlation of IT with measures of IQ. Of the 9 correlations computed between the 3 IT tasks and the 3 AH5 scores, only the LIT task had a significant negative correlation with IQ (LIT/AH5A r = -0.27 (P<.05); LIT/AH5B r = -0.41 (P<.01); LIT/AH5C r = -39 (P<.01)). VIT/AH5 correlations were negative, but did not reach significance. The AIT task showed a slight and surprising positive association with IQ scores.

2.3.2. The effect of strategy on performance.

The third speed hypothesis (1c) was negative, and anticipated that introspected strategies would be irrelevant to IT tasks. This was evaluated by comparing mean scores for strategy reporting and non-reporting individuals on the IT measures (see table 2.3.2.). Only in the case of the VIT task was IT significantly more brief for individuals reporting performance strategies over those who reported no strategy on the VIT task (t = 2.41, P<.01). All other comparisons were non-significant, suggesting that in all other ways the two groups were comparable. VIT was thus affected by some task-specific strategic effect. On one interpretation this may indicate the difficulties in masking simple stimuli on a computer monitor. However no such effect was apparent for the LIT task.

Table 2.3.2. Mean (SD) for subjects divided into groups according to whether they reported using a performance strategy on VIT or not.

Test administered	Strategy users		No strategy reported		*t*
n	24		17		
	Mean	SD	Mean	SD	
AIT (msec)	76.3	36.2	94.4	35.6	-1.60
VIT (msec)	33.4	17.0	56.1	29.3	-2.41 *
LIT (msec)	41.9	52.2	34.2	28.8	0.61
BPP correct	17.6	1.4	17.5	1.5	0.12
AH5A correct	15.7	4.3	15.9	3.8	-0.17
AH5B correct	19.8	4.3	18.7	3.6	0.87
AH5C(AH5A+AH5B)	35.5	7.9	34.6	5.6	0.41

(* t-comparison P<.03; F-test for equivalence of variance also P<.03.)

The hypotheses derived from strategic theories were somewhat different. Hypothesis 2a suggested that ITs would correlate with one another only because the sample combined individuals who did (and did not) use strategies on the experimental tasks. Dividing the sample into two groups, one reporting any strategy, the other not showed that similar pattern of associations was seen for the subsamples to that seen in the overall population; namely that the two visual IT tasks correlate to a similar degree, and that LIT is correlated with measures of non-verbal IQ (see table 2.3.3).

The prediction that strategy users would be of higher IQ than those who did not make any such introspection (hypothesis 2b) was not supported (see table 2.3.2). Hypothesis 2c, that the best performance strategies would occur in the most intelligent subjects was examined by first classifying the different strategy types reported. Five types of strategy were described, some of uncertain relevance to non-visual tasks. The strategies reported were "paying attention"; "apparent motion" (in whatever form); "a race between two lines to get to the bottom"; "watch for the short line and press the other response key" (a logical opposite); and no response.

Table 2.3.3. Correlations between IT and IQ variables for the sample, broken down by strategy reporting on VIT task or not.

	Strategy		No Strategy	
n	24		17	
AIT/VIT	05		26	
AIT/LIT	11		-03	
VIT/LIT	39	*	42	*
AIT/AH5A	10		16	
VIT/AH5A	-13		-24	
LIT/AH5A	-20		-54	**
AIT/AH5B	24		37	
VIT/AH5B	-30		-07	
LIT/AH5B	-40	*	-50	**

(All decimal points dropped; one-tailed test; significance key; * = P<.05; **=P<.01).

2.3.3. The effect of different strategy types on performance.

The effect these strategies may have had on the IT and IQ measures was considered by using strategy type as a independent variable to categorise individuals within tasks. Oneway analysis of variance assessed whether there were any significant differences across all 5 strategy types. To control for the possibility of multiple t comparisons producing chance differences between subgroups, *post-hoc* Scheffe tests with a criterion of P<.05 were used to evaluate the putative differences (see table 2.3.4).

Table 2.3.4. Mean (SD) of experimental variables divided by strategies reported on the VIT task.

Strategy	n	AIT		VIT		LIT		AH5A		AH5B	
Attention	7	72.1	20.2	28.6	17.7	49.1	72.6	16.4	3.2	20.0	4.5
Apparent motion	10	90.0	45.2	30.8	16.3	29.1	26.8	15.7	4.6	20.4	4.8
Race to bottom	2	70.0	40.2	58.5	6.4	94.5	99.0	11.5	0.0	15.5	2.1
Logical opposite	5	57.0	29.5	35.4	14.3	36.4	28.7	16.8	5.8	20.0	3.9
No response	17	94.4	35.6	56.1	29.3	34.2	28.8	15.9	3.8	18.7	3.6
F (5,40)		1.401		2.981		1.081		0.618		0.778	
P <		n.s.		.04		n.s.		n.s.		n.s.	

(n.s. = No significant difference between strategy groups.)

The only significant difference across strategy groups was on the VIT task; all others showed no difference. When this analysis was re-computed between the three larger groups (those reporting attention, apparent-motion, or no strategy reported), the effects remained similar to that seen when the groups were more broadly classified. *Post-hoc* Scheffe tests were all non-significant, showing that none of the comparisons made of differences between subsamples were significantly different from chance. This emphatically rejects hypothesis 2c.

The possibility that mental speed combines with strategy to optimise performance on other tests of perceptual threshold was tested by dividing the AIT score at the mean, and crosstabulating this against subjects whom reported strategies or not on VIT. Fourteen individuals had faster AIT and reported strategies, 4 had faster AIT with no reported strategy, 10 had slower AIT and strategy, and 13 had slower AIT and no strategy. This pattern of frequencies was almost significantly different from chance (x^2 with Yates' correction = 3.583, P<.06). Only a small proportion of strategy users on VIT tasks had slower AIT to start with. This was in keeping with hypothesis 3, and supports the possibility that strategy and speed are complementary rather than exclusive processes on IT tasks.

2.4. Discussion.

The results of the current study sporadically support the IT/IQ phenomena as products of processing speed, vulnerable to some task-specific strategy, rather than strategy *per se*. Though the AIT and VIT tasks failed to associate with IQ, or were sometimes vulnerable to strategy, LIT measured information-intake speed, was not affected by performance strategy, and was associated with non-verbal measures of intelligence (irrespective of whether one used the full sample, or subdivided them by strategy). When the possibility of strategic effects were directly considered, the only reliable phenomena related to the use of a specific strategy on VIT, rather than a general strategy effective across a number of IT tasks. This use of a specific strategy bore no relation to IQ, and did not account for VIT's moderate association with IQ.

Given the imprecise nature of computer-monitor presented IT stimuli, the experimental nature of the AIT task, and the homogeneity of the sample, these results are relatively clear. The putative strategy effect did not have any significant effect within LIT, and it remains to be seen whether LIT has a systematic vulnerability to strategy; the original study by Longstreth *et al* (1986) made no reference to strategic effects by subjects, though he was initially sceptical of IT studies. Possibly LIT is more practical when using computer monitors to present IT tasks. There was little evidence to support the view that the different types of strategies described across conditions provided specific advantages in stimulus discrimination for the subjects reporting them. All three speed hypotheses thus receive support, if not in the strongest form.

A closer consideration of the strategic subanalysis confirms that IQ scores were extremely similar between groups, and this may have partially concealed the suggestion of a difference between individuals reporting any strategy, as compared to those who reported none. Further studies in this style may find that the use of the AH6 would provide greater variation between subjects. One might also consider using a less IQ-homogenous group, so as to evaluate differences in strategy type or production on IT tasks. The subdivision of performance by reported strategies presented some ingenious categories for "general" strategies, and one can only assume that some subjects thought that strategies pertaining to VIT were requested, rather than strategies applicable across all three tasks. The process of strategy elicitation would therefore appear crucially dependent on precise and repeated non-directive questioning.

The independent measurement of attention, motivation, or the organisation of responses to the task outwith an IT paradigm would not answer critics of IT, as performance on IT may involve strategies other than those measured in previously conducted tasks. It is therefore necessary to conduct a microanalysis of behaviour within the IT task itself, objections to IT being operationalised in terms of performance within IT trials. For example, attention could be defined as the number of easy discriminations wrongly responded to following a return to an easier psychophysical level from a harder one. Alternatively, one could give IT from the bottom, rather than the top, of the psychophysical threshold, making the task more attention-dominated, and also free from rehearsal of task-specific strategies at easily discriminable IT exposures.

The use of the AIT task in this study prevented a clear addressing of the central problem of IT, which is seen exclusively on visual tasks. Subsequent studies will attempt to compensate for problems of interpretation the current study has raised by a closer investigation of the processes involved in strategic development across IT testing sessions.

Chapter Three

Does perceptual intake speed reflect intelligent use of feedback in an IT task? - The effect of restricted feedback.

3.1.1. Introduction.

In eliciting and measuring mental processes the psychologist has to control for the uncertain nature of the subject's response. A subject may attend poorly to an experimental task due to tiredness or intoxication, and thus show impaired performance. Alternatively, performance may be improved by some process that has little to do with the task being administered. Apparently objective and neutral psychological tests may produce a range of scores not attributable to the quality being measured in the first place. Even psychophysiological measures, for example polygraph monitoring of a heart-rate or skin conductivity, can be affected by factors other than anxiety to a stress-producing question: erotic thoughts, emotional memories or pain may give rise to similar psychophysiological responses (Lykken, 1979). Cognitive tasks are equally susceptible to variations in how subjects approach them: Miller (1956) showed how the limitations of the short-term memory (typically able to recall 7 ± 2 digits) could be overcome by 'chunking' the single items into sequences. These variations in approach that tend to enhance task performance could be called 'strategies' (especially if they involve insight and consciousness); and individual differences in strategy-use may account for for correlations between one variable and another - for example between IT and IQ.

The development and rehearsal of such strategies may be readily facilitated by the substantial number of trials required for psychological measurement, and the personal approach taken by the subject This active aspect of the subject's behaviour in an experimental situation can be seen as a 'translator process', in which the response to sensory input can become a stimulus to an (unpredictable) stimulus action. Once this rule of translation has been built up, putting it into use can often precede the signal which would normally initiate it (Welford, 1958). The end product of such repetition will be a strategy - whether it involves conscious processes, automatised skills, or both (Welford, 1972). This current experiment considers how task-specific IT performance strategies are developed, in relation to the processes of skill acquisition and measured intelligence.

The development of effective performance stratagems requires feedback; and feedback becomes particularly important in situations when tasks give no indication as to how well the individual is performing. The provision of false feedback by the experimenter would deprive subjects of information that is normally vital to strategy development. Thus, by disrupting the feedback-dependent processes of skill acquisition, putative IT-related strategy skills may be elucidated. Consequently, if IT is affected by strategy. the effect should be attributable to individual differences in non-strategic features.

3.1.2. Skill Acquisition.

An early review by Thorndike (1908) could not decide whether individual performance converges (reduce variability) or diverges (increase variability) following training on a task. He attributed this equivocal conclusion to the individual differences in skill acquisition. Rather more recently, Fleishman *et al* (1972) described three factors in the determination of ability-performance relations; broad cognitive abilities that determine an individual's initial task performance; perceptuo-motor abilities which increasingly determine performance as one practices on the task; and task-specific abilities which differ from both cognitive and perceptuo-motor abilities. These processes of skill acquisition are generally demonstrated using a reaction-time paradigm. Ackerman (1987) found that the between-subject RT standard deviation reduced by an average of 34% from initial performance levels following practice on a task within the abilities of the respondents, so indicating that the inter-individual variability of performance decreases with practice. He also found that task complexity affected the initial level of variability and its corresponding rate of attenuation following practice. Performance variability decreases only when the information-processing requirements of the task are especially consistent (i.e. if the subject deals with particular stimuli in the same manner over a number of repetitive trials) (Ackerman *et al*, 1987).

The principles of skill acquisition remain the same irrespective of the theoretical model invoked. Thus, where Fitts and Posner (1967) propose cognitive, associative and autonomous stages, Anderson (1982; 1983) describes declarative, knowledge-compiling and procedural stages, and Schneider and Shiffrin (1977) advocate controlled, mixed-controlled and automatic stages, the differences between these systems are largely semantic. All these theories describe how the subject, initially consciously involved in skill acquisition, has their skill refined by the feedback ensuing from mistakes they make when applying the new skill, until performance of the skill hardly needs any thought. While strategies are being developed there is an external feedback loop relating to the discrepancy ("error quantity") between the subject's current performance and some desired standard. Knowledge of the results, or external feedback is acted on to minimise this discrepancy between standard and current performance; feedback, in the case of experimental tasks is discrete, and obvious errors in performance give rise to apparent correction.

The initial confrontation with an experimental task tends to involve a high demand on the cognitive and attentional system. Performance in this phase is slow and errorprone, as many task-related strategies may be generated, and attention is mostly given to understanding and performing the task in question. With practice, however, the performance shows a marked increase in speed and accuracy, leading to reduced requirements on attention. At this point strategies to accurately perform the task are fully formulated.

An important feature of skill acquisition after practice is that of task consistency (Fisk and Schneider, 1983). However, the initial requirement of a particular task is not necessarily consistency; all novel events have to prove they are consistent in the first place, in turn requiring conscious monitoring of the stimulus for change by the subject. With practice, a consistent task facilitates skill acquisition, unlike inconsistent tasks, which remains cognitively involving over long phases of practice (Shiffrin and Schneider, 1977). The contrast between the two kinds of task is particularly pronounced when the task in question requires a moderate degree of thought. Individual differences in performance on tasks with substantial inconsistency remain dominated by the first principle of skill acquisition - conscious thought. Individual differences on tasks with no consistent components show no reduction in their correlation with cognitive ability over practice, as each trial or task requires attention; each example of inconsistency requires controlled processing, decreasing the strength of learned associations that would make the task easier.

3.1.3. Elementary cognitive tests.

Continuous monitoring of simple IQ-correlated laboratory tasks is necessary because of the unpredictability of the stimulus; thus, variable fore-periods may be used prior to the presentation of choice reaction-time stimuli; target tones in an auditory evoked potential test occur randomly in a run of regular stimuli; and subjects are not generally able to anticipate the speed with which IT stimuli are presented. These test characteristics are predominantly attributable to good test methodology, and the important (and common) aspect of such tasks is their estimation of information-processing speed (in whatever guise the author prefers). However, though these tasks might seem so simple and methodologically sound as to be apparently strategy-free, it has been argued that strategic performance can account for many of the results they have generated - if the results mean anything in the first place.

Marr and Sternberg (1987) have argued that mental speed lacks relevance across the diversity of cultures and subcultures upon which this general model is supposed to apply. This is because basic tasks with their subtle differences of milliseconds in execution or intake bestow little advantage to the examinee so blessed, except in the specific context of the experimental task. Being of doubtful ecological relevance, the differential patterns of attention and resource allocation shown in these tasks may merely favour some individuals (those motivated to spend 20 minutes completing a choice-reaction time task) over others on simple laboratory measures of information-processing speed.

3.1.4. Strategic perspectives on skills.

Though skills have, at their basis, stimulus analysis, recognition matching, and error checking (Baron, 1978), knowledge of a task is also necessary. Part of the triarchic theory of intelligence emphasises knowledge acquisition components as a vital aspect of performance in their selectively encoding, combination, and upgrading of information (Sternberg, 1984), so enabling the subject to acquire strategy-relevant versus irrelevant information (Marr and Sternberg, 1986). This reflects the fact that some individuals apparently minimise the redundancy of their sensory input during tasks, by noting genuinely useful cues to guide subsequent action (Annett and Kay, 1956). If an individual can identify the salient information in a situation or a stimulus, they can devote their information-processing capacities to less basic considerations than the task itself.

Even in a simple task, many metacomponential issues are allegedly touched upon. The subject must identify the specific requirements of the problem in question; select a solution strategy and the appropriate performance components to correctly execute it; monitor and modify this as necessary; assess which performance components remain consistent across the variations within the task; decide whether all the effort in these operations is actually worth the trouble (i.e, a "means-ends analysis"); and eventually automatise the process. An error at any of these stages will slow or impair performance (Sternberg, 1985).

Evidence for metacomponential processing has been found by looking at the strategic differences shown by individuals on information-processing tasks, as described in chapter 1 of this thesis. As well as differences in solution strategy associated with specific and general cognitive processes, there also seem to be ability-related differences in the allocation of attentional resources. Thus, when learning new information, attentional allocation was determined by the difficulty of the stimuli among academically better 12 year olds; difficulty had little effect on the allocation of attention amongst more mediocre children (Bransford *et al* , 1982).

3.1.5. Manipulating skill acquisition within IT.

The majority of IT trials are at, or above, an individual's final IT, and the task itself is consistent. However the exposure duration of IT stimuli vary according to the accuracy (or otherwise) of the subject. A population of subjects may find themselves refining a response strategy during this phase of practice and task-relevant feedback as their knowledge-acquisition components selectively encode a phenomena seemingly inevitable with a two-line visual IT paradigm; apparent-motion (see section 1.7 of this thesis). Presentation of IT at a range of easy and hard durations may give metacognitive processes an opportunity to develop an IT-relevant strategy, this being based on the combination of perception of apparent motion and knowledge of how to respond to the task. This may account for the significantly briefer ITs seen in subjects who report an apparent motion phenomenology during IT testing (Mackenzie and Bingham, 1985; Mackenzie and Cumming, 1986).

By increasing the need for stimulus analysis of IT stimuli, the recognition of cues (and the matching of these cues to particular outcomes) may be reduced, as information relevant to knowledge-acquisition components is restricted. The alternative is that strategic effects are occurring at a preconscious level, with the process of strategy development being not necessarily under the control of the metacognitive system.

3.1.6. A challenge to strategy theorists.

Brand (1987) has challenged strategy-theorists to elaborate upon the attribution of the correlation between measures of IQ and simple tasks measuring information-processing speed to differential strategy use. Following the dependence strategy formation has on information and feedback to start with, he suggests that strategy-using testees should be especially influenced by feedback - and thus by false feedback - as an indicator of how well they are doing on a task where most stimuli are too brief to verify.

If visual IT task was given from below, rather than above the psychophysical threshold, discrimination of the stimulus would become more dependent upon the visual intake speed of the subject - rather than any special way of responding to the task. In the absence of self-evident feedback regarding semi-refined performance strategies to an apparently impossible task, test feedback should become particularly important to strategy modification. False feedback should be doubly-distracting to strategy development, as the apparently refined technique on a particular task would not necessarily be acknowledged by unreliable, computer-admininstered feedback. The only possible advantage a subject could have under such conditions other than faster intake speed would be general, for example, attentiveness (assuming that the development of a strategy requires practice in the first place). This study thus attempts to pit speed versus strategy theories against one another using two types of visual IT task; an initially-impossible form using ascending exposure durations (ADIT), and the conventional version (VIT).

3.1.7. Hypotheses of this study.

Different predictions can be made regarding these experimental manipulations of feedback and task, according to whether one regards IT as a measure of intake speed or an end product of strategic processes. Speed theorists would anticipate that:

1) There will be no difference between IT values derived from an IT task with target-exposures starting below the perceptual threshold, and a conventional IT task which presents stimuli at initially longer durations.

2) The two IT tasks would correlate significantly and positively with each other.

3) As feedback is irrelevant to IT performance, no difference in IT would be seen for an initially-impossible IT task presented with either truthful or false feedback.

4) As the main source of variance in task performance is some parameter of mental speed or fluid intelligence, significant negative correlations would be observed between the two IT tasks and scores on measures of IQ.

The first hypothesis addresses a general effect that an initially impossible task would have for subjects in either of the two feedback conditions: that of practising a strategy. The second hypothesis looks at specific effects of feedback on performance both in the short-term, and on subsequent (and comparable) tasks. Strategy theoreticians such as Sternberg, Ceci, or Howe, convinced of the wholesale influence of strategic effects, would anticipate that false feedback from the task would impair strategy refinement and subsequent IT. (They would also suggest that experimental tasks require a micro-analysis of any strategies reported, preferably following an inspection of self-reports regarding how the subjects reported doing the task. They would expect that those subjects who produced the best performance on the tasks to show the most effective strategies, and also to be the most intelligent subjects). Those individuals who consider a place for the possible biasing effects on the IT task of the specific apparent motion strategy would expect to see it in both IT tasks, irrespective of feedback.

3.2. Method

3.2.1. Design

The experiment followed an independent subjects design, in which subjects were allocated to either a truthful or false feedback condition for ADIT. All subjects first completed the Alice Heim 5 (AH5; Heim, 1967) test of ability, which comprised two sections; verbal (AH5A) and non-verbal (AH5B). These two sections were added together to provide a total score (AH5C). This was followed by ADIT and the conventional IT task (VIT). After each IT task subjects completed a self-report response sheet upon which they were asked to report any particular technique they had used in the task to make it easier. The independent variable of the experiment was allocation to one of the two feedback conditions; the dependent variables were the two IT tasks, the number of trials required to complete VIT, the three AH5 scores, and the self-reported strategies returned.

3.2.2. Subjects.

A total of 51 subjects were tested for this experiment. Thirty two were female, 16 male; 3 individuals did not enter this information on their record forms. Participation in this experiment was considered part of a second-year practical class in differential psychology. Mean age of the group was 21, though 3 subjects were mature students. All subjects had normal or corrected eyesight.

3.2.3. Elucidating strategies.

As this study was using undergraduate students, it was assumed that the method of self-reported written introspections would be appropriate. Brebner and Cooper (1986) found that this technique was as efficient as any strategy-articulating process, and had the advantage of minimising the unconscious biasing that verbal enquiries into strategy could have. In the case of the self-report, subjects were asked to write down on their response sheet how they would tell a friend the easiest way of telling the difference between the two lines.

3.2.4. Equipment

Other than the AH5 and self-reports, the experiment used a network of BBC microcomputers to present the two IT tasks. There are limitations concerning the speed at which the phosphorescent coating of a computer monitor can present stimuli; a Raster scan cannot reliably refresh the signal presented to the screen below about 20 milliseconds. Though this means that exposure durations below this cannot be reliably presented, Deary, Caryl, Egan and Wight (1989) established that monitor ITs still correlated positively with other IT tasks. In particular, an IT task with vertical stimuli correlated with equivalent tasks using alphanumeric stimuli at 0.39 ($n = 46$; $P<.01$), with horizontal stimuli at 0.48 ($n = 51$; $P<.001$), and with auditory stimuli at 0.24 ($n = 68$; $P<.05$). When the correlation between an IT task using vertical lines and scores on the AH5 was corrected for attenuation of IQ variance, the revised IT-IQ correlation for 50 subjects ranged between -.52 and -.60 ($P<.001$). This demonstrated that an effective IT can be derived using a computer monitor to present stimuli, even when one tests a high-ability sample.

3.2.5. The ADIT task.

The ADIT program presented IT stimuli (a fixation point followed by two lines, one a third longer than the other either on the left or right of the display, followed by a full overlay mask) at an initial duration of 200 milliseconds. Responses were recorded from the "Z" and "/" (backslash) keys of the computer keyboard, all other keys being disabled by the program. Following 12 correctly-discriminated trials at this duration, the subject was told that the next few trials would be rather more hard to see. From a base of 20 milliseconds the exposure duration of the stimuli increased by 1 millisecond whenever the subject had made three errors of discrimination at a given exposure. This continued until the subject has completed 15 trials at a given exposure, with less than 3 errors (corresponding to a minimum accuracy of 85% at the particular duration observed). This criterion forced a psychophysical curve onto the performance of the subject.

3.2.6. Feedback from the ADIT task.

In the truthful feedback condition the ADIT task stopped every 10 trials to let subjects have a break from testing; for those subjects who were scoring at, or above 80% target discrimination accuracy at the current exposure duration, a message reading "WELL DONE" was displayed. If this condition had not been achieved, a message was displayed reading "PLEASE PAY ATTENTION" instead. In the false feedback condition, this message was given randomly, rather than according to performance over the past few trials. Though trial-by-trial feedback would provide a stronger manipulation, it would also make manipulation of feedback more obvious.

3.2.7. The VIT task.

VIT is a standard IT task which presents stimuli on a computer monitor. This computerisation enables the task to be used in schools, hospitals or doctor's surgeries, providing they have a BBC microcomputer, a monitor and a disc-drive. The stimuli and manner of response were as described for the ADIT task. However, IT stimuli were presented initially at 200 msec, this exposure being adjusted according to the PEST algorithm (see section 2.2.3.3.). The number of trials required to find a VIT was designated PTRIALS.

3.2.8. Procedure.

The practical class occurred over three days. On the first and third days all subjects were given the truthful feedback condition, while those on the second were placed in the false feedback condition. Prior to all experimental tasks, subjects completed the AH5; after this, the class was divided in half, so that each subject could be tested independently. For all subjects the testing sequence was thus as follows;

AH5 - ADIT - self-report - VIT - self-report   END OF SESSION

3.3. Results.

3.3.1. Overall results for the study.

All data was analysed using the SPSSx package (Nie *et al*, 1975). One subject had to be omitted from the data for the VIT IT task following their experience of symptoms suggestive of mild epilepsy (brought on by the computer monitor presenting stimuli in an apparently stroboscopic manner). A further 10 subjects were correctly discriminating IT stimuli at durations below 20 milliseconds; as the monitor could not reliably present stimuli that mapped the psychophysical function below 20 millisecond exposures, these individuals were excluded from further data analysis.

This left 30 subjects in the truthful feedback condition, 21 in the false feedback condition. Table 3.1.1 presents summary statistics for the sample, and their intercorrelation.

Table 3.3.1. Correlation matrix of summary variables (with mean and standard deviation) for the sample (n = 51)

	VIT		PTRIALS		AH5A		AH5B		AH5C		MEAN	SD
ADIT	36	**	36	**	-07		19		07		54.6	21.1
VIT			33	**	-15		03		-06		50.5	18.3
PTRIALS					-31	*	-12		-23		119.8	51.3
AH5A							63	***	90	***	15.6	4.3
AH5B									91	***	19.7	4.4
AH5C											35.3	7.9

(Decimal points dropped, one-tailed test, significance * = P<.05; ** = P<.01 ; *** = P<.001.)

There was no overall difference between the two IT conditions for the full sample (t = -1.30, n.s.), and the two tasks correlated at 0.36 (P<.01). Thus the two tasks were equivalent, supporting the first two experimental hypotheses. The two halves of the AH5 correlated at 0.63 (P<.001). Even after correcting the correlations for restricted variance of IQ, the IT tasks did not correlate significantly with scores from the AH5, rejecting the fourth speed hypothesis.

3.3.2. The effect of manipulated feedback.

Combining data from the two days into one data set does not take into account the manipulation of feedback, which may have confused some subjects more than others;

table 3.3.2 presents independent-subjects *t*-tests for the experimental variables according to whether the subject was in a truthful or false feedback condition.

Table 3.3.2. t-tests comparing performance for true / false feedback conditions.

	Truthful feedback		False feedback		t	P<
	Mean	SD	Mean	SD		
n	30		21			
ADIT	52.5	20.8	57.7	21.7	-0.87	n.s
VIT	54.0	18.9	45.6	16.7	1.65	n.s.
PTRIALS	123.0	40.5	130.3	63.2	-1.21	n.s.
AH5A	16.6	4.0	14.1	4.4	2.12	.04
AH5B	19.9	4.2	19.3	4.8	-0.47	n.s.
AH5C	36.6	7.5	33.5	8.1	1.40	n.s.

(n.s. = no significant difference.)

Table 3.3.2 shows that there was no significant difference between the feedback conditions for the ADIT task (t = -0.87, n.s.), demonstrating that feedback was irrelevant to performance on this special version of IT . VIT differences almost reached significance. Only in the case of performance on the verbal subscale of the AH5 did subjects in the two conditions differ on an IQ variable. This is possibly an artefact of testing a science, rather than arts-based psychology practical class on that particular day. A within-group effect was observed for those subjects who experienced false feedback on ADIT in that their subsequent VIT IT was significantly briefer (t =3.23, $P<.004$); this was not the case for those subjects who received truthful feedback regarding ADIT performance (t =0.35, n.s). Despite the manipulation of giving subjects false feedback regarding their performance on an apparently impossible task, performance on a subsequent (and easier) IT task was enhanced. Table 3.3.3

breaks the correlation matrix down according to the testing condition, so that the relationships for the two testing days can be examined separately.

Table 3.3.3. Correlation matrix for study, broken down by feedback conditions. (Above diagonal, true feedback (n=30); below, false feedback (n=21)).

	ADIT	VIT	PTRIALS	AH5A	AH5B	AH5C
ADIT		26	60 **	-11	24	08
VIT	63 **		27	-35 *	-10	-24
PTRIALS	09	48 *		17	04	-07
AH5A	08	-06	-38 *		69 **	91 **
AH5B	15	19	-22	58 **		92 **
AH5C	13	08	-33	88 **	90 **	

(Decimal point dropped; one-tailed test; significance * = $P<.05$; ** = $P<.01$).

Table 3.3.3 shows that the IQ assessment for each day was very reliable; the same cannot be said for the two IT variants, as it is only when subjects were given misleading feedback that the two ITs appeared to be measuring the same thing. This might be an effect of subjects having to be more reliant on their own senses when being unable to rely on the information given by an automated task. Though on the day of truthful feedback to an ascending duration IT task, the VIT task correlated with the AH5 verbal IQ measure ($r = -.35$, $P<.05$), the fact that only 1 of 12 IT/IQ correlations correlated significantly suggests that this is a chance result.

3.3.3. Differential patterns of strategy use on the IT task.

Post-hoc analysis of the self-reports produced six types of introspected strategy: "attention" (involving the subject saying that one should watch the screen and pay attention); apparent motion (where the self-report mentioned the flash and movement of the backward mask over-writing the shorter line of the target stimulus, and being used as a cue to press the response key for the other stimulus line); a "race to the bottom" (where the two mask lines apparently race to the bottom of the stimulus, the line which gets to the bottom first being the shorter stimulus); a "logical opposite" strategy (where one watched for the shorter of the two stimulus lines, and pressing the opposite); and an "afterimage" strategy (which claimed to facilitate the discriminanda by an inspection of the afterimage on the screen). As all monitor screens had been previously calibrated to prevent this possibility, it is unsurprising that this was only reported once. A further 16 subjects did not complete their introspection forms; as it is not possible to evaluate whether they had strategies (but couldn't express them) or not, they compromised an "uninterested" strategy sample to compare to the more reflective sample described above.

These strategic categories were used as the basis for a statistical analysis of strategic effects on IT; subjects who had truthful feedback on ADIT were used as a model of the expected frequencies for particular strategy types under initially impossible conditions. x^2 (with Yates' correction) for strategy type in the ADIT task by feedback was 8.7 with 5 degrees of freedom; x^2 (with Yates' correction) for VIT was 9.2; both were non-significant (see tables 3.3.4 and 3.3.5). Thus the range and frequency of strategy types did not vary according to either feedback or task variety.

Table 3.3.4 Frequencies of self-reported strategies on ADIT by feedback condition.

Strategy type	Feedback		ADIT (msec)			
	True	False	Mean	SD	Mean	SD
Pay attention and relax	7	4	44.0	21.9	43.4	22.3
Apparent motion	6	8	45.8	17.7	54.6	17.4
Watch lines race to bottom	4	1	43.5	2.6	42.0	
Logical opposite	2	2	58.5	8.5	68.5	9.2
Optical (after-image)	1	1	47.0		47.0	
No response	10	5	65.4	24.0	76.4	24.7
Total	30	21	52.5	20.8	57.7	21.7

Table 3.3.5. Frequency of particular strategies (with mean and standard deviation (SD) for VIT).

Strategy type	Feedback		IT (msec)			
	True	False	Mean	SD	Mean	SD
Pay attention and relax	9	3	48.3	13.2	39.3	0.6
Apparent motion	4	6	45.8	11.0	34.7	15.8
Watch lines race to bottom	3	1	63.0	9.0	39.0	
Logical opposite	3	2	36.0	8.9	42.5	2.1
Optical (after-image)	1	2	79.0		53.5	19.1
No response	10	7	62.6	23.8	57.1	18.1
Total	30	21	54.0	18.9	45.6	16.7

One-way analysis of variance considered these strategies as independent variables, with ADIT, VIT and AH5 scores as independent variables. There was a significant difference of ADIT values across groups (F(5,45)=3.18, P<.02), this effect being mostly attributable to the comparison of subjects paying attention versus those not following any strategy reported. A similar effect was observed for the VIT task (F(5,45)=3.30, P<.02), with inspection of the means showing, unsurprisingly, that attentiveness to the task provided lower IT values than indifference. However, *post-hoc* Scheffe tests of these differences were not significant (see tables 3.3.6 and 3.3.7). None of the strategy categories were notable by their significantly higher verbal or non-verbal IQ scores.

Table 3.3.6. Means and standard deviations (SD) of ADIT and AH5 scores (all Ss, by strategy).

Strategy type		ADIT		AH5A		AH5B		AH5C	
	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pay attention and relax	11	43.7	20.8	15.1	3.1	18.3	3.9	33.4	6.9
Apparent motion	14	50.9	17.7	16.9	4.9	20.9	3.5	37.8	7.5
Watch lines race to bottom	5	43.2	2.4	14.4	3.9	19.2	4.1	33.6	7.7
Logical opposite	4	63.3	9.4	17.0	5.4	19.5	4.5	36.5	9.5
Optical (after-image)	2	44.0	4.2	17.9	2.8	23.5	2.1	40.5	4.9
No response	15	69.1	23.7	14.6	4.2	19.3	5.7	33.9	8.9
Total	51	54.6	21.1	15.6	4.3	19.7	4.4	35.3	7.9
F (5,45)		3.18		0.65		0.73		0.73	
P<		.02		n.s.		n.s.		n.s.	

These data were pooled for subjects to see whether the constant application of self-reported strategies had any special effect on performance. Subjects who employed consistent strategies for both IT tasks tended to have briefer ITs than those who were either inconsistent in the strategy they employed, or declined from reporting any in the first place. Again, no difference in AH5 scores was seen (see table 3.3.8).

Table 3.3.7. Means/SDs of VIT and AH5 scores (all Ss, by strategy).

Strategy type		VIT		AH5A		AH5B		AH5C	
	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pay attention and relax	12	46.1	12.0	15.8	4.3	18.6	3.8	34.3	7.3
Apparent motion	10	39.1	14.6	16.4	5.0	20.5	4.2	36.9	8.5
lines race to bottom	4	57.0	14.1	15.0	4.2	19.0	4.7	34.0	8.9
Logical opposite	5	38.6	7.3	18.0	5.1	19.8	4.0	37.8	8.9
Optical (after-image)	3	62.0	20.0	15.0	3.6	22.3	2.5	37.3	6.1
No response	17	60.4	21.2	14.6	3.9	19.6	5.5	34.2	8.4
Total	51	50.5	18.3	15.6	4.3	19.7	4.4	35.3	7.9
F (5,45)		3.30		0.58		0.42		0.32	
P<		.02		n.s.		n.s.		n.s.	

Table 3.3.8. Means/SDs for ADIT, VIT, and PTRIALS by consistent strategy use.

Strategy type		ADIT		VIT		PTRIALS	
	n	Mean	SD	Mean	SD	Mean	SD
Pay attention and relax	10	42.1	21.3	41.7	3.9	113.8	49.1
Apparent motion	10	46.3	14.5	39.1	14.6	106.8	55.3
Watch lines race to bottom	4	42.3	1.3	57.0	14.1	113.7	31.1
Logical opposite	4	63.1	9.4	37.5	7.9	105.3	26.6
Inconsistent strategies	16	64.1	19.3	61.4	20.6	128.3	53.8
No response	6	68.6	29.7	61.3	19.7	151.4	69.9
Total	51	50.5	18.3	15.6	4.3	19.7	4.4
F (6,44)		2.71		3.75		0.65	
P<		.03		.005		n.s.	

A two-way ANOVA was used to examine the simultaneous effects of strategy and feedback on the ADIT task, with subjects being dichotomised into either strategy reporters or not. This showed that strategy users had faster ADITs than non-users, that feedback had no effect on ADIT, and that there was no interaction between strategy use and the feedback condition (see table 3.3.10).

Table 3.3.10. Summary of analysis table examining the effects of strategy and feedback on ADIT.

	DF	Σ of squares	Mean square	F-ratio	Significance
Feedback	1	646.5	646.5	1.774	n.s.
Strategy	1	4736.7	4736.7	13.001	.001
Feedback x strategy	1	63.7	63.7	0.175	n.s.
Total	50	22263.9	445.3		

An inspection of the means from table 3.3.6 indicated substantial differences between the strategic subgroups, with individuals who did not report strategies having slower ADITs. The two-way ANOVA above was recomputed excluding these individuals,with strategy-reporting individuals being divided into three more plausible strategy groups; paying attention, using apparent motion, or other strategies. This found no significant effects for strategy, feedback, or the interaction of these two variables (see table 3.3.11).

Table 3.3.11. Summary of analysis table examining the effects of strategy and feedback on the ADIT task, excluding individuals who did not complete self-reports.

	DF	Σ of squares	Mean square	F-ratio	Significance
Feedback	1	122.5	122.5	0.425	n.s.
Strategy	2	716.4	358.1	1.231	n.s
Feedback x strategy	2	212.3	106.1	0.365	n.s.
Total	35	9964.6	284.7		

3.4 Discussion

This study found that the two IT tasks, approaching the psychophysical threshold from two different directions, did not differ significantly from one another, and were actually correlated with one another. The ADIT task was not significantly affected by false feedback. Even when the correlation between these IT tasks and an IQ measure was corrected for restriction of ability range, neither task was significantly associated with measures of intelligence.

The manipulation of feedback by simple computer screen messages did not provide a very strong manipulation, as the remarks made could have been considered as general statements, rather than descriptions of incorrectness. Subsequently, feedback could be manipulated using some more material reward, for example tokens for every 5 trials correctly discriminated, in conjunction with false feedback. This would motivate subjects to perform optimally on the task, as they would be under the impression that their performance was reflected in their token count. Subjects attempting to develop strategies given false feedback would have apparent material evidence that their strategies were ineffective, irrespective of their actual performance. If the ADITs of individuals subsequently found to be strategy users were significantly slower than strategy-free individuals given truthful feedback and honest reports of their accumulating token wealth, one could conclude that strategic development requires feedback from the task in question. Currently, however, the lack of effect that feedback had on ADIT suggests that any strategic factor within the task is not defined by a model which involves "learning skills".

The discovery that individuals who actively introspect on the task had faster ADITs than individuals who do not reflects the importance of actively engaging the interest and motivation of the subject on experimental tasks. Though it also suggests some caution when interpreting visual IT results derived from group testing without some simultaneous index of the attention the subject is giving to the task, this issue has already been considered by researchers using IT. Anderson (1986) ensures that children (who are notoriously erratic in their attention to experimental tasks) are presented with IT tasks which interweave easy to discriminate unmasked stimuli , and stimuli which are more conventionally briefly-presented and masked. Individual testing of subjects on visual IT paradigms also reduces this problem, as the experimenter can motivate the subject during the task if their attention or enthusiasm appears to be reducing. The motivation of the subject to do an laboratory task is considered important by critics of the information-processing speed model of intelligence (Marr and Sternberg, 1987) and was demonstrated in this study. However, the point is relatively trivial, as it can be reduced provided the experimenter pays due attention to the procedural needs of the subject. In any case, it is not central to properly cognitive conceptions of strategy. The main implication of this result is thus that the quality of the IT task is important.

When the actively introspecting sample were divided into groups reporting either attention, apparent motion, or miscellaneous strategies on the ADIT task, they did not differ significantly from one another. This could be interpreted by a hard speed theorist of IT as evidence of the irrelevance of differing strategy types on ADIT. Alternatively, it could be said, presentation of ADIT stimuli on a computer monitor screen are unreliable and inconsistent. One way to resolve this problem of interpretation would be to use an ADIT paradigm, but present the stimuli with either a matrix of light-emitting diodes, or a tachistoscope. Recoding the VIT introspection data according to the type of strategy used to solve the IT tasks implied that some strategies were more effective than others, but that no strategy strongly emerged as accounting for this result. In addition, the distribution of strategy types was not affected by false feedback. It thus remains to be seen whether the unspecified variance in the IT task is associated, in some way, with the differences in self-reports regarding how the task is solved.

The debate about introspective data is as old as psychology; and for every Ribot, who believed how thought operated was unimportant compared to its content, there is a Watson who prefers simple observations of behaviour. Quite how one can investigate the content of an individual's thought depends upon one's preferred philosophical and methodological approach to psychology. Evans (1980) reported that introspection was returning to fashion in psychology as a way of accessing mental processes associated with conscious thought. He emphasised that one should distinguish phenomenological reports (e.g. subjective colour, perceptual illusions) and strategies, as all too often research on strategies assumes that the subject is able to observe and report the mental processing underlying their behaviour, and that the reported strategy has mediated their behaviour. However, only certain processes are introspectable; typically those that are general, conscious, and slow, rather than specific, automatic, and quick (Fodor, 1983). Even this assumption is generous, as it assumes a ready access by the individual to their own thoughts, where it may be the case that the individual is unable to introspect, or is inconsistent in how they report their observations.

The introspection technique used in this study was dependent on observing one's own behaviour. If there are individual differences in the ability to introspect (and there are no clear criteria for deciding which processes are introspectable (as opposed to those which are not)), one has to have a way of falsifiably demonstrating that reported strategies work as causal processes underlying behaviour. Kosslyn and Pomeranz (1977) suggest a way around this problem, advocating that one should back up introspections with behavioural measures, for example response latencies. The current study instead considered the perceptual thresholds of subjects supposedly employing particular strategies, and produced a diversity of approaches, none of which strongly emerged as definitively useful strategies. By testing subjects individually, subsequent studies can ensure that all subjects are given sufficient individual attention and encouragement to minimise indifference and maximise attentiveness to the task. If all subjects are attending the task, then one can more closely examine the nature of the strategies mediating the IT task, under more specific experimental conditions.

This study has rejected the possibility that IT-penetrating strategies are a function of refined practice on the task, and has shown that an initially- impossible task correlates as well with an apparently easy IT task to the same degree as any other computer-monitor presented IT stimulus. The restricted IQ variance of a student population, combined with the imprecision of the monitor-presented stimuli suggest that two other modifications must be made to further experiments; a more normal sample should be obtained, and a more precise technique for IT administration.

Chapter Four

Are specific IT-penetrating strategies prevented by concurrent tasks?*

4.1.1. Introduction

"As an article of faith" it was recently written, "it is ... accepted that higher cognitive processes that involve strategies are conscious and under voluntary control. This model assumes that such processes are amenable to verbal report, and that strategies can be altered by conscious decisions *e.g.* verbal instructions" (Evans, 1990). One "higher cognitive process" subsumed by this assumption is intelligence, intelligence being, according to this viewpoint, a special case of strategic processing. General strategic theories of intelligence emphasise the upper levels of cognitive control, in particular conscious processes like deliberation, planning, and skill development. Quite how well these processes correspond to lower level theories of intelligence, with their emphasis on the speed and efficiency of basic (typically unconscious) mental processes is unclear, though both compete as modern paradigms for investigating *g* .

The two previous chapters have addressed the possibility that general strategies affect performance on the IT task; neither found any strong evidence for this possibility. However, some individuals reported seeing some apparent motion associated with the the overwriting of the IT stimulus by the mask, and these cues gave individuals briefer ITs than individuals who did not report perceiving apparent motion. The current study investigates general aspects of these specific strategies, and places demands on upper (*i.e.* conscious) levels of control using a dual task paradigm to administer IT simultaneously with a consciousness-involving task. This manipulation directly tests the level of control at which IT occurs and the degree to which IT is dependent on

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* A shortened version of this chapter has since been accepted for publication in **Intelligence** 16:1, 1992.

attentional resources. If the use of apparent motion cues during visual IT is driven by general metastrategies, it is hypothesised, one would expect a dual task paradigm involving IT to disrupt this process. However, if IT and IT-penetrating strategies are based on lower-level processes, IT performance would not be particularly affected by conscious attention being focussed upon on another task.

4.1.2. Is IT dependent on attention?

One possible mediating factor in the use of specific IT-penetrating strategies is attention. Sternberg (1984) suggested that the allocation of attentional resources is a major metacomponent of intelligence, and Mackintosh's critical discussion concerning the resurgence of speed-of-processing and IQ research developed this viewpoint. In this article Mackintosh suggested that more intelligent people had better attentional resources rather than faster mental processes, and were thus able to hold information, or some strategy, in working memory while doing a simple task (Mackintosh, 1986). Both strategic and information-processing theories of intelligence have suggested that *g* is due to 'attentional resources'. Whether one regards this as a specific and partially conscious metacomponent (Sternberg, 1984, 1985), or a general mental process (Hunt, 1980) depends on the theoretical level of cognitive control one prefers. However, both views agree that generalised "poor attentional resources" in low-IQ subjects may, in some way, account for their poor performance on measures of information processing speed rather than slower mental processes *per se* - a common objection to studies of mental speed.

Attentional processes can be broad or narrow. Broad attentional processes are general, and occur when one is conscious but not directly engaged in a task. Narrow attentional processes are directed, and are exemplified when one is occupied on a task. Whatever controls these processes has to consider upper and lower levels of attentional control (Norman and Shallice, 1985). Upper levels are voluntary, conscious and essentially under metacognitive direction, requiring sustained attention to be kept in operation. Lower levels control processes are triggered by particular stimulus configurations, and are partially independent of specific attentional resources. Attentional resources, themselves finite, limit the degree of upper level control (Shiffrin and Schneider, 1977).

The 'attentional resources' metaphor involves 3 separate conceptual assumptions; energy or fuel, structures, and skills (Hirst and Kalmar, 1987). These concepts are used to examine whether attention can be seen as a single central capacity, or a series of multiple resource pools. The energy metaphor refers to the need for attentional processes to draw 'fuel' from a finite, unspecified reservoir. Fuel has to pass through the bottleneck of consciousness; thus, when simultaneous demands are made on the same process, interference occurs - implying a hierachical structure to the attentional process (Eysenck, 1985). That parallel sensory channels are able to function independently, despite being used simultaneously, provides some evidence for autonomous attentional structures lower down this hierachy (Broadbent, 1984). The idea of attentional skills as a resource involves the assumption that one can consciously direct attentional processes as and when they are needed, and an acknowledgement of the learning process. Evidence for this is primarily seen in the ability for people to coordinate between two competing tasks (Duncan, 1979), and the discovery that, given a sufficient number of trials, performance under the competing condition approaches the level of performance under the single condition (Logan, 1978).

4.1.3. Dual task performance.

It has become paradigmatic to examine attentional processing resources with dual task studies (Navon, 1984). These studies require that the additional task be secondary; present discrete stimuli that impose constant load; be carried out at a forced, experimenter-decreed pace; and only compete with the primary task for the shared process. Dual task paradigms require constituent tasks that are practised, simple, combine relatively easily, and enable some alternation of attention (Brown, 1978). One way of determining the resource-limitation of competing tasks is to manipulate the resource reservoirs they are assumed to draw upon. Attentional resource reservoirs can be characterised in 3 dimensions: their stimulus characteristics (for example, auditory versus visual); their internal code (*i.e.* a visual or verbal task); and their response mode (manual or verbal). The degree to which there is interference between tasks can be estimated by a consideration of these three dimensions (Hirst and Kalmar, 1987). As dual task methodologies provide a way of quantifying the amount of shared variance in competing cognitive tasks, they can be used to dissociate limited central processing capacity from the efficient encoding of information (Stankov, 1988).

This theoretical background provides a methodology to examine the degree to which perception of apparent motion cues post-IT stimuli are due to general strategic processes involving upper level attentional control. Giving subjects an IT task involving a visual stimulus, a visual representation, and a manual response in parallel with a task which involves an auditory stimulus, verbal representation and verbal responses would maximise difficulty at the most general attentional level, whilst keeping the integrity of the independent cognitive processes. The ideal parallel task for such a study is the Paced Auditory Serial Addition Task (PASAT; Gronwall, 1977). PASAT is a test intended to measure the degree to which a testee's attention and concentration have been affected by concussion. PASAT loads working memory by asking subjects to add numbers in pairs, storing one in working memory whilst they add this to the number presented previously. A typical (correct) exchange would be as follows:

Tester says :	2	4	5	3	1	
Testee replies :			6	9	8	4 ....

The example above shows how the two previous numbers presented must be added in pairs, the product being presented in the interval between stimuli. Forced pacing of these digits at 2 or 4 second intervals makes PASAT a challenging task, though one allegedly unrelated to IQ (Gronwall and Wrightson, 1981). It is unclear whether individual differences in PASAT are associated with individual differences in resource availability, as the appropriate experimental studies have not been conducted; however the task, which requires some sustained combination of memory capacity, memory updating and processing of order information, is undoubtedly challenging, and demands the full conscious attention of the subject.

The relationship between attentional resources and intelligence has been examined on the grounds that the central pool of cognitive resources may be nothing more than an experimental version of psychometric *g*. The attentional resources theory of *g* takes the following syllogistic form; competing tasks measure intelligence; the amount of available attentional resources determines performance on competing tasks; thus attentional resources underlie intelligence. To conclude this, one must observe the following conditions; firstly, the tasks must show a decrement in performance between single and competing conditions; secondly, the components of the competing tasks must show higher correlations with measures of intelligence than do single tasks (Stankov, 1989). Stankov (1983) has suggested that 2 mechanisms - 'collapse' and 'compensation' - may mediate the higher correlations obtained from the components of competing tasks. Collapse is inferred by the decrement in performance from single to dual task conditions and the increase in the correlation between the task(s) and the IQ measures, while compensation assumes no shift in either the mean performance between conditions, or the correlation between tasks and IQ.

4.1.4. Intentions of the study.

The current study adopts a slightly different methodology to those conducted previously, as the brief exposures that IT requires cannot be reliably presented on a computer monitor that has a 20 msec screen refresh rate. Thus, though an IT may be derived that has a small association with both other IT tasks, and with IQ, the IT derived will be less reliable than ITs presented at more exact durations. The current study attempts to overcome this problem by using a matrix of light-emitting diodes (LEDs) to present stimuli.

Earlier studies used university undergraduates, a popular, if over-utilised and homogeneous sample for studies of individual differences in ability. The current study uses young adults recruited from work training schemes, with a less restricted range of ability, the intention being to test strategic hypotheses within a naturalistic population. Previous strategy elicitation has involved individuals writing their introspections down after they have completed an IT task. Some chose to write nothing, some wrote elaborate strategies that were inappropriate to the IT situation. The current study tests subjects individually, and asks them, at a point in the IT process where stimuli are being shown at difficult-to-discriminate points immediately prior to IT, to describe, as they do the task, how they make their discriminations. This should obtain better phenomenological descriptions *within* the strategic process.

Resource theory is relatively unbiased regarding the cause of the IT/IQ correlation. It would be more concerned with the degree and amount of attentional resource requirements required for IT performance, and ask whether strategic processes during IT tasks involve a greater amount of these resources. If shorter ITs are due to metastrategies directing the identification and application of apparent motion cues during IT, then the introduction of a competing task requiring general attentional resources should limit the application of these metacognitive processes. An alternative possibility is that the dual task condition would affect strategy execution, rather than initiation, which would lead to the strategy being used less efficiently, increase the variability of IT performed under competing conditions, and also make strategy users more dependent upon resources. Either way, resource limitation makes it is likely that there would be increased correlations between and IT measured under competing conditions and IQ.

If a simple 'speed' perspective is adopted, it might be thought that IT is a mandatory encoding process, and subsequently, that it is at a low level of control. If this is true, then, irrespective of subgroups of subjects who report 'strategic' phenomena, interference with upper level processes should not especially disrupt IT performance. If individuals who previously reported apparent motion effects still show briefer IT in the dual task condition, it suggests that the perception and application of an apparent motion cues do not occur at a general, conscious level. If IT is related to IQ due to some general speed substrate, an IT/IQ correlation should be found for all subjects, irrespective of strategy or condition; this correlation should increase following the introduction of the competing task and the increased dependence on encoding processes.

The general strategic perspective would anticipate metastrategic processes in the dual task condition. As attentional processes and higher IQ predicate the superior metacognitive processes of the strategy user, these should be found, as should some evidence of skill acquisition, such as extended practice, and a correlation between this and better performance. As metastrategic processes direct multi-tasking, ITs should remain faster for strategy users in the competing condition, due to some degree of compensation in this group - which could be inferred by the greater reduction in PASAT performance during the competing condition. As the IT/IQ correlation is an artefact of combining samples with differing apparent ITs and strategies (lower IQ samples having slow ITs because they don't know how to do the task, compared to higher IQ subjects having some strategic approach which causes their faster IT), inconsistently applied strategies may reduce the IT_2/IQ correlation further.

4.1.5. Hypotheses of the study.

Thus, as with previous studies, differential predictions derive from whether one adopts a speed or strategy explanation for the IT/IQ phenomena. Speed theorists would anticipate that apparent motion is an artefact of the specific IT paradigm, and that the metastrategic processes to account for this are irrelevant. It would also hold that this apparent motion strategy does not require special amounts of resources because it is essentially preconscious, and simply augments encoding speed. This encoding speed would correlate with IQ irrespective of the experimental condition. It would thus predict:

1a. Strategy and non-strategy groups on the IT tasks would not be differentially affected by the introduction of the competing task.

1b. The only performance difference between individuals reporting apparent-motion (or not) would be for an apparent motion-specific task : IT.

1c. The IT tasks would correlate negatively with measures of IQ for all groups, and would increase in correlation following the introduction of the competing task.

Predictions based on the assumption that the IT/IQ relationship is an artefact of metastrategic attentional processes expressed through an experimental task would acknowledge the sustained involvement of these processes in the dual task condition, and the likely disruption of performance following the introduction of this competing task. Combining this point with the ideas of Sternberg and Mackintosh, strategic predictions should be that;

2a. Strategy reporters would have higher IQs than non-strategy reporters.

2b. Strategy reporters would have better attentional processes (as measured by PASAT) than non-strategy reporters.

2c. Because strategies are refined with practice, strategy reporters will show significantly more trials on IT prior to IT derivation.

2d. Strategy users would have a significant negative correlation between the number of trials taken to derive IT, and their final IT.

2e. Because good IT performance is dependent on metastrategy use, the faster ITs seen for this group during the dual task condition, will be obtained only by some degree of task compensation. This means that their PASAT performance will be worse than for non-strategy users.

2f. As the IT/IQ correlation is an artefact of combining quite separate groups, this correlation will break down when correlations between ITs and IQ are calculated individually for strategy-using and non-using subjects.

The resource perspective is primarily concerned with how the two competing tasks are performed together, as compared to separately, and the degree to which strategies require increased or reduced amounts of these resources. It hypothesises;

3a. If fast ITs are due to conscious attentional 'metastrategies' directing the identification and application of apparent motion cues during IT, then the introduction of a competing task requiring general attentional resources should limit the application of these metacognitive processes.

3b. If strategy users are more dependent on general attentional resources for strategy execution than non-strategy users, the introduction of the competing task will increase the variability of IT_2 for strategy users (reflecting differences in the efficiency of applying this strategy under difficult conditions).

3c. The greater dependence placed on resources in the dual task condition will increase the range of IT scores for all subjects, increasing the correlation between IT and IQ.

4.2. Method.

4.2.1. Design.

The experiment followed a same-subjects design in which all subjects received the same conditions; psychometric testing, IT and PASAT. IT and PASAT conditions were counter-balanced to control for order effects. Subjects were allocated *post-hoc* to strategy reporting or non-reporting groups, strategy being operationally defined as a consciously described technique of using apparent motion to guide IT discriminations at difficult exposure durations. The dependent variables (IQ, IT alone (IT_1), IT completed under PASAT (IT_2), PASAT alone (P_1), PASAT conducted simultaneously with IT (P_2), and the trials needed to derive IT_1 (T_1) and IT_2 (T_2)) are described below.

4.2.2. Subjects.

Twenty nine subjects (23 female, 6 male) were tested. They were obtained from two sources: an Edinburgh Youth Training Institute, and Boroughmuir school. They were of normal ability (Mean Raven's IQ = 101.45 (SD= 15.4) as extrapolated linearly from Table XV (pp. SPM 31) of the Manual for the Standard Progressive

Matrices), and had a mean age of 17.3 years (SD = 6 months). All had normal, or corrected to normal vision.

4.2.3. Psychometric tests of intelligence and personality.

4.2.3.1. **The Standard Progressive Matrices** (SPM; Raven, 1977).

The SPM measure non-verbal *g* by having the subject identify the missing section of a pattern matrix from a series of possible choices.

4.2.3.2. **The Cattell Culture-Fair measure of *g*** (CCF; Cattell, 1973).

The CCF measures 4 variants of non-verbal *g*. As with the SPM, the subject must identify the appropriate answer from a set of possible alternatives.

4.2.3.3. **The Alice Heim 2 Measure of Intelligence** (AH2; Heim, Watts and Simmonds, 1974).

The AH2 has three subscales, which measure vocabulary (AHV); arithmetic ability (AHN); and non-verbal performance (AHV). The three scales added together provides a general score (AH2T).

4.2.3.4. **The Mill-Hill Vocabulary Scale Part B - Synonyms** (MHB; Raven, *op cit*).

The MHB measures vocabulary by having subjects underline the word closest in meaning to a target word; to the extent that vocabulary is partly acquired by learning, the MHB is partly a measure of *g* c.

4.2.3.5. **The Eysenck Personality Questionnaire** (EPQ; Eysenck and Eysenck, 1975).

The EPQ measures 3 well-validated and independent dimensions of personality; extraversion (E); neuroticism (N); and psychoticism (P). It also has a Lie (L) scale that measures the degree to which the subject is responding to the questionnaire according to social desirability of the item.

4.2.4. Experimental tasks: 1. IT

A BBC B micro-computer with a visual-IT program (VPEST) was used to measure IT. The program controlled an LED display device, and recorded all responses from the subject. ITs were displayed on a standard 7-segment LED digit-generating character, mounted within a small casing. The display appeared as two vertical parallel lines, each composed of an upper and lower LED segment, with three parallel horizontal LEDs, each half as short as the vertical sections, set between the two vertical bars. In total, the display appeared as a stylised character eight, set at an angle of about 10 degrees (see fig. 4.2.i).

All IT trials involved the subject being initially presented with a fixation-point (the middle horizontal LED) for 500 milliseconds. This was followed by an inter-stimulus -interval of 500 milliseconds. The subject was then presented with the target stimulus, which was composed of both vertical LEDs being lit on one side of the display, the top vertical LED being lit on the other, both vertical lines being joined by the top-most LED. Whether the long line was presented on the left or right side of the display was randomly decided by the program, with the exposure duration being decided by a PEST algorithm (see section 2.2.3.3). This was followed immediately by a mask, after which the subject made his or her response. To limit over-impulsive responses, there was an inbuilt delay of 200 milliseconds before a response was registered by the computer. The mask remained on until the subject had made his or her response. This routine was repeated until an IT was derived.

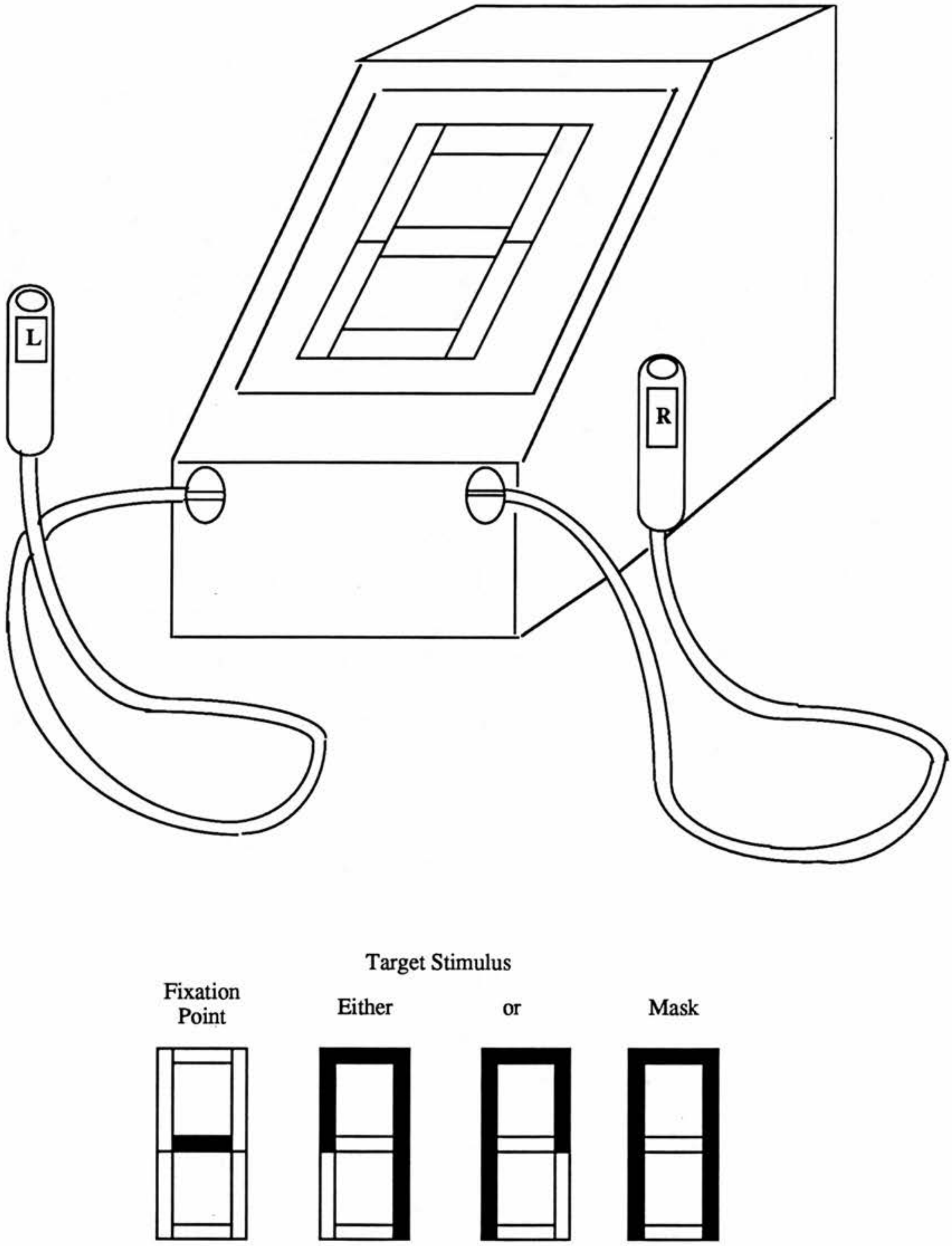


Fig. 4.2.i. LED IT box, using a 7-segment digit-generating character.

4.2.5. Experimental tasks: 2. PASAT.

PASAT was administered by a pre-recorded tape which presented 61 single digits at 4-second intervals. Subjects were not tested on this procedure until they had achieved a pre-determined criterion of 10 untimed PASAT trials correct with no assistance. This was followed by a 40 item PASAT rehearsal, enabling subjects to be fully familiar with the sustained pressure of the timed version of the task. This was also disregarded from final analysis, as it was immediately followed by the experimental PASAT measure (P_1). For the dual task condition, a number of 4-second PASAT blocks were recorded into a single recording (P_2). This ensured that P_2 paced IT_2, irrespective of the time required by the subject to derive the IT measure.

4.2.6. Strategy Elicitation.

During IT_1, when the IT-controlling algorithm was at a step-size of 4, and a suitable inter-stimulus interval occurred, the experimenter prompted the subject to describe how they made their decision concerning the side the long target line was presented on. In particular, subjects were asked to describe what they saw, and say how they made their decision regarding the side the longer line was shown on. This was written *verbatim.* The IT_2 condition did not enable an appropriate inter-stimulus interval, as the subject was doing PASAT at the same time. Thus subjects had to describe any strategy used after the IT was completed.

4.2.7. Procedure.

Psychometric tests had been completed at a previous session. Subjects were randomly allocated to either IT or PASAT first. The instructions for IT were as follows:

"You are going to do the Inspection-Time task. In this, all you have to do is to see whether a long line appears on one side of the screen or the other. For each trial please look at the middle of this display. (Indicate LED box.) The small bar in the middle will light up. This is to make sure you are looking in the right place, and that you are paying attention. There will be a short gap followed by a long line and a short line, joined at the top. The long line will be on the left or the right, but it will be shown only for a little while. It will then be replaced by the entire display being lit up, bar the middle line. When this happens, you indicate your decision as to whether the long line was on the left or the right side by pressing the appropriate button.

The test is concerned with the accuracy of your response, not the speed of it, so take as much time over the decision if you find you need to. This is important, as the time for which you see the lines will adjust according to how you do the task, going from very easy to quite difficult. Sometimes you won't be able to tell on which side the line was longer. When this happens, please make a guess. In fact though you'll often feel that you're guessing, your guesses may well be right. Have you any questions ?"

Subjects then completed the IT task. The instructions for PASAT were equally specific; they said:

"You will hear a list of single numbers read one after another. I want you to add the numbers in pairs and give your answer aloud. Add each number to the one just before it, not to your answer. Add the second number to the first, the third to the second, and so on."

"Right, now we will try the first trial. The first one is just as fast as the practice part you have just done, but is a little longer. Don't worry if you make a mistake or leave some out. I want to see not only how long you can keep going without stopping, but also how quickly you can pick up again if you do stop."

Subjects were tested on the two IT conditions twice, with the mean of these two runs through the tasks being the values used in the analysis.After being tested on IT_1 and P_1 tasks, subjects were given a short break and introduced to the combined IT-PASAT condition. They were told they were going to do this 'adding-up' task alongside IT. The apparent challenge this presented was reduced by the subject being informed of their good performance on the IT task. To help subjects start the dual task condition, PASAT was started after the subject had completed two correct blocks of IT trials. This ensured that PASAT was subsidiary to IT, rather than in direct competition with it. Individual differences in IT obtaining rates were accommodated by having the extended version of PASAT pace performance on the other task.

4.3. Results.

To generate a provisional *g* factor within a small sample of subjects, test scores were ranked and then averaged according to verbal (VR), non-verbal (PR) and total (TR) scores. VR was composed of scores from the MHB, AH2V and AH2N tests, PR from the SPM, CCF and AH2P tests. TR was all the tests added together. The two IT_1 conditions were added together to give the testees their basic IT_1 score; the same was done for IT_2, the PASAT condition corresponding to this, and the trials for these IT conditions.

4.3.1. Statistics for the full sample.

Inspection of table 4.3.1 shows that IT was slowed about 30 msec following the introduction of the competing task, with PASAT being reduced by about 10%. In both IT tasks, it typically took about 85 trials to derive an IT value. Correlational analysis of this data showed that the two IT tasks correlated at 0.73 ($p< .001$); IT was associated more modestly with the two PASAT tasks. Both IT tasks correlated with the IQ measures, but the higher associations were to be seen for IT when administered in parallel with PASAT. Hypothesis 1c, that the IT-IQ correlations would be found for both types of IT task, and would increase in the dual task condition, was thus supported. PASAT proved highly reliable across conditions (r = 0.93, P<.001), and also correlated well with IQ (for further details of this result, see Egan, 1988). The number of trials required to derive an IT did not correlate with the subsequent brevity of the IT.

Table 4.3.1. Means, SDs and intercorrelations between measures for all subjects (n=29).

	IT_2	P_1	P_2	T_1	T_2	VR	PR	TR	Mean	SD
IT_1	73 ***	-37 *	-38 *	-04	11	-31 *	-43 **	-38 *	34.2	13.3
IT_2		-21	-28	05	-26	-44 **	-53 ***	-47 **	63.7	37.4
P_1			93 ***	26	02	46 **	64 ***	53 ***	85.7	18.3
P_2				20	03	53 ***	65 ***	56 ***	75.9	18.6
T_1					-26	-10	-04	-10	87.6	19.3
T_2						21	29	24	84.9	24.1
VR							83 ***	91 ***	15.0	6.5
PR								95 ***	15.0	7.3
TR									15.0	6.9

(* = P<.05; ** = P<.01; *** = P<.001; All decimal points dropped; all comparisons one-tailed.)

4.3.2. Analysis of subjects by allocation to strategy or non-strategy groups.

Seventeen (59%) of the 29 subjects reported the use of apparent-motion cues, mostly within the first IT session. The remainder developed the strategy in the second run of the IT task alone. None reported any change in technique following the expression of apparent motion strategy, nor did they report being able to use apparent motion cues during the dual task condition. Non-users numbered 12 subjects (the remaining 41% of the sample).

Table 4.3.2. Summary statistics for all subjects, divided by reported apparent motion or not.

	Strategy users		Non strategy users		*t*	P
n	17		12			
VR	17.3	6.2	11.9	5.8	-2.40	.05
PR	16.1	7.7	13.5	6.8	-0.97	n.s.
TR	16.4	7.1	13.0	6.3	-1.36	n.s.
P	4.5	3.8	4.5	3.8	-0.02	n.s.
E	15.6	3.6	13.3	4.7	-1.44	n.s.
N	10.7	6.5	13.6	4.8	1.40	n.s.
L	6.1	5.2	8.5	4.6	1.31	n.s.
IT_1	28.8	9.6	42.0	14.2	3.00	.02
IT_2	53.7	23.5	77.9	49.7	1.75	n.s.
P_1	85.6	18.3	85.2	20.0	0.16	n.s.
P_2	76.2	19.0	75.4	18.0	-0.11	n.s.
T_1	88.1	26.0	87.1	13.6	0.13	n.s.
T_2	87.0	17.6	83.4	28.3	0.38	n.s.

Table 4.3.2. summarises the means and standard deviations for the subjects, broken-down according to whether they reported using apparent motion cues or not. Both groups had ITs that had slowed by about 35 msec after the introduction of the competing task, which was itself slowed by about 10% when conducted in parallel with IT. Individuals who reported apparent motion cues showed significantly higher verbal ability than those who did not report these cues (t = -2.40, $p<.03$). This difference

did not extend into non-verbal ability (t = -0.97, n.s.). This supports a weak form of hypothesis 2a, in that strategy reporting subjects are more (verbally) intelligent than individuals who do not report strategies, and refutes the speed theory that predicts the opposite - that the only difference between apparent motion reporters and non-reporters is on the IT task itself (hypothesis 1b).

Individuals who reportedusing apparent motion cues to guide IT discriminations had significantly briefer IT_1 than non-reporters (t = 3.00, P<.006); however following the introduction of the additional load, the IT_2 SD for strategy users was significantly lower than that of non-users (F(12,17) = 4.46, p<.007), a result in the opposite direction to that predicted by hypothesis 3b. As strategy reporters showed less variation (as well as briefer IT) than individuals not reporting these effects, mean IT_2 were compared with a non-parametric test, and found non-significant (Mann-Whitney rank-sum W test, W= 203.5, U = 78.5, n.s.). Hypotheses 2b and 2c, that strategy users would be significantly better on tests of attention, and that they would practise for longer on IT prior to its derivation were not supported; the two groups were not distinguished by any differences on either P_1 or P_2 attention tasks, or on the number of trials required to derive IT.

To assess the possibility of a differential effect of PASAT on IT for strategy users, a two-way repeated measures ANOVA was computed using IT as the within-group factor, and strategy use as the between group factor. Strategy users differed from non-strategy users on the IT task (F(1,26)=4.76, P<.04), and IT became significantly more difficult for the same individuals following the introduction of the auditory pacing task (F (1,26) = 29.71, P<.001); both results one would anticipate. There was no interaction between IT task and strategy use (F(1,26) = 0.95, n.s.). These results support hypothesis 1c of the speed theory, which suggests that strategic IT performance in the dual task condition will not be differentially affected by simultaneous involvement with PASAT. Strategy users did not differ from non-strategy users on the number of trials required to derive IT for the two IT conditions ($F(1,26)=.20$, n.s.); nor were there significantly more trials required to derive an IT after the introduction of PASAT ($F(1,26) = .13$, n.s.). There was no interaction between IT trials alone, or in parallel with PASAT, and strategy use ($F(1,26) = 0.04$, n.s.). These results show that the trials required to derive IT did not differentiate either IT tasks or strategy users from one another. The same ANOVA model was used to evaluate the effect of IT on PASAT. Strategy users did not differ from non-strategy users on PASAT ($F(1,26)=.00$, n.s.), though PASAT became significantly more difficult for the same individuals following the introduction of IT ($F(1,26) = 59.1$, $P<.001$). There was no interaction between PASAT performance and strategy use ($F(1,26) = 0.48$, n.s.). This result rejects the possibility that better performance on IT_2 by strategy users is a consequence of their differential attention to the IT task over PASAT (hypothesis 2e).

Power statistics were used to estimate the magnitude of the strategic effect seen on the IT task. Power analysis involves the calculation of *d* (the ratio of the differences between means divided by the pooled standard deviation (Cohen, 1988)). For IT_1, *d* equalled - 0.99, suggesting a very strong effect of strategy; when the PASAT condition was introduced, *d* for IT_2 was - 0.64. This suggests that the apparent motion effect, though still occurring, had reduced by about one third.

4.3.3. Correlations within strategy-reporting and non-reporting subjects.

Table 4.4.3. presents the correlation matrices for the two experimental groups. For subjects reporting strategies on IT_1, the subsequent IT_2/P_2 correlation was - 0.62 ($P<.01$); for non-users the correlation was - 0.09 (n.s.). This suggested that those with faster IT scores showed better PASAT scores, providing they were already aware of apparent motion cues. The use of these cues was not, however, a function of

practice, as strategy hypothesis 2d advanced; though the correlations were negative, they were both small and non-significant for both groups.

Table 4.3.3. Correlation matrices for strategy and non-strategy reporting subjects.

Above diagonal, subjects not reporting strategies (n=12), below diagonal, subjects reporting the use of an apparent motion strategy on the IT task (n=17).

	IT_1	IT_2	P_1	P_2	T_1	T_2	VR	PR	TR
IT_1		78 ***	-12	-14	04	-06	-06	-34	-25
IT_2	50 *		07	-09	09	-41	-26	-40	-36
P_1	-74 ***	-65 ***		90 ***	30	-16	55 *	60 *	54 *
P_2	-72 ***	-62 ***	96 ***		19	07	68 **	62 **	60 *
T_1	-27	-06	26	24		-42	05	-01	-02
T_2	19	-32	08	02	-20		57 *	64 *	58 *
VR	-22	-56 **	50 *	50 *	-29	15		86 ***	92 ***
PR	-47 *	-77 ***	68 ***	67 **	-06	22	84 ***		96 ***
TR	-37	-60 **	56 **	56 **	-21	15	92 ***	95 ***	

(All decimal points dropped, one-tailed significance test; * = $P<.05$; ** = $P<.01$; *** = $P<.001$.)

Speed theory prediction 1c - that IT scores would correlate significantly and negatively with IQ - was the opposite of the strategic prediction 2f. This anticipated no IT/IQ correlations when correlation coefficients were computed independently for the two subgroups. In both samples the IT/IQ correlations were found; these increased in size following the introduction of a parallel task, so supporting hypothesis 3c. The correlations were larger, and generally significant for individuals reporting strategy use during IT_2; the association was stronger for the non-verbal composite IQ estimate (see figure 4.3.3.i).

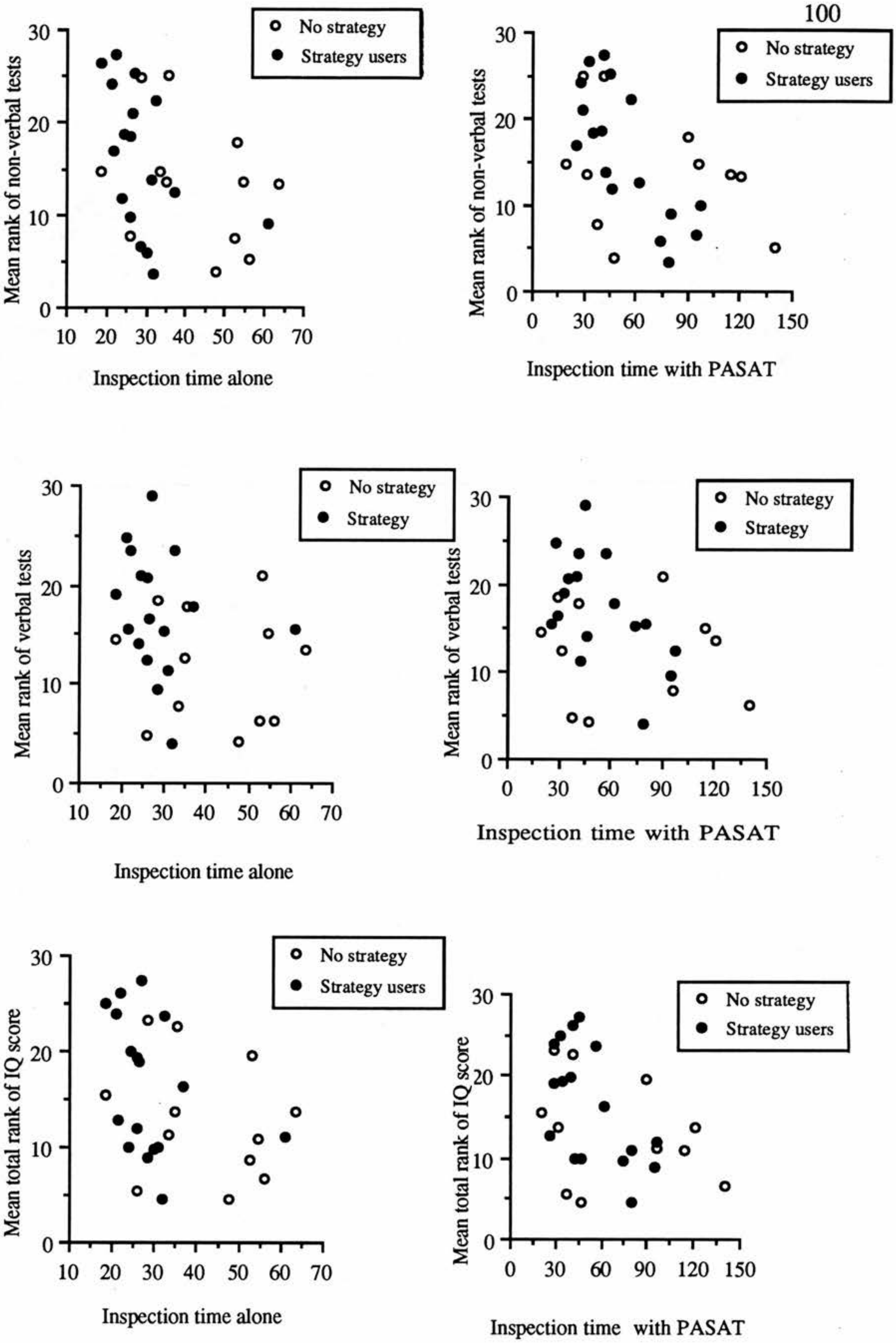


Fig. 4.3.4.i. Scattergrams between IT_1 and IT_2 and VR, PR, and TR IQ measures, subdivided by strategy reporting.

4.3.5. Controlling for the effect of PASAT on IT.

Because PASAT was substantially correlated with measures of IQ, the effect PASAT had on the IT/IQ correlation for the dual task condition was partialled out. For the full sample, the VR, PR and TR/IT_2 correlations were -0.36 (P<.03), -0.48 (P<.005), and -0.39 (P<.02) respectively. When the sample was subdivided into strategy-users and non-users, these became -0.36 (P<.08), -0.60 (P<.007), and -0.38 (P<.08) for strategy-users, and -0.27 and -0.38 (both n.s.) for VR and TR, and -0.44 (P<.08) for PR. Thus the IT_2/IQ correlation was not simply an artefact of the PASAT/IQ association.

4.3.6. The effect of personality on IT.

Table 4.3.6. Correlation (Pearson's *r*) between personality and IT tasks.

	All subjects		Strategy		No strategy	
n	29		17		12	
	IT_1	IT_2	IT_1	IT_2	IT_1	IT_2
P	13	01	33	27	-00	-17
E	-39 *	-44 **	28	14	-74 **	-68 **
N	-01	13	-37	-09	10	20
L	25	30	06	57	27	03

(All decimal points dropped, one-tailed test; significance values are * = P<.05; ** = P<.01.)

These results show that for both IT conditions, individuals who do not report the use of apparent motion cues on IT tasks show significant negative correlations between their E scores and IT, suggesting that, for this particular population, the more extraverted the individual, the shorter their IT.

4.4. Discussion

This study has found the following; (i) ITs have a strong tendency to be faster in subjects previously designated as strategy-using, despite their involvement with a parallel consciousness-involving task; (ii) that subjects who report using apparent motion strategies are higher in verbal ability than individuals who do not report apparent motion phenomenology; (iii) that the use of these strategies is not related in any simple way to superior attentional processes in strategy reporting subjects; and, most crucially, (iv) that the IT/IQ relationship is not destroyed by having subjects conduct a parallel task - not even one as IQ-related, and thus demanding of intelligence, short-term memory and attention, as PASAT.

One possibility considered by this study was that IT-pentrating strategies require more attentional resources through their demands on working memory , and thus involve upper level control. It was predicted that if this was so, then individuals who report strategies on a standard IT task would show a greater input of resources into the task following the introduction of the parallel task. Some of the results from the study bear this out. Firstly, there was dual task interference between IT and PASAT, implying that both tasks draw on some common resource, irrespective of strategy use. High correlations between IT and PASAT tasks were seen for strategy users whether the tasks were correlated within conditions, or cross-sequentially; however, no correlation of any kind between IT and PASAT tasks were seen for subjects who did not report strategies, implying some consistent common task variance for strategy users not seen for the other group. The raised IT/IQ correlations, again, particularly for strategy users, imply that a dual-task variant of IT indexed resources more strongly in strategy users than non-users.

The results also suggest that some lower-level process is occurring, which enables IT to be conducted while attention is largely directed to another, consciousness-consuming task, and also enables individuals previously designated as strategy users to obtain faster ITs than non-strategy users. Does this suggest that perceptual encoding speed occurs semi-independently of general attentional processes, and that, for some subjects, noticing apparent motion cues is part of this process? Perception of apparent motion can occur even at very brief exposures, is preattentive, and based on parallel visual processing (Dick, Vilman and Gagi, 1987). One might hypothesise that apparent motion reporters have greater output from short-range apparent motion detectors. This output occurs at a low-level and preconsciously, and serves as an input to consciousness and eventual description. Thus apparent motion perception augments basic information processing speed, rather than replaces it.

Significant IT/IQ correlations for strategy users have not been observed previously. Several reasons may account for this. Firstly, the competing condition may trigger more efficient processing than the single task condition. Secondly, because strategy users are performing so well, they are operating closer to an optimal level, thus imposing greater dependence on individual differences. It should also be noted that the two strategic studies conducted by Mackenzie *et al* (1985; 1986) involved the use of a computer monitor to present stimuli, an IT task which presented stimuli in a horizontal orientation (the left end of the stimulus lines varying in the point at which they finished), and samples of students. These would limit the precision of the IT, make for inconsistencies regarding whether both stimulus lines are in foveal vision or not, and restrict the IQ variance. None of these difficulties were apparent in the current study.

Perceptual differences between individuals have been explained by reference to individual differences in personality. In particular, artefacts associated with visual masking have previously appeared smaller in individuals with high arousal (introverts), and pronounced in those with low arousal (extraverts) (Eysenck and Eysenck (1985)). Eysenck and Eysenck thus speculate that cortical arousal serves to facilitate discriminations such as those between two successive stimuli presented close together in space and time. Though there was a suggestion of differences in E between the groups, this was not statistically significant. The correlation between E and IT was very strong in subjects who did not report apparent motion, but absent for those who did. The reason for this effect is open to speculation, as the prediction from personality theory is straightforward: apparent motion reporters are lower in E.

This study confirmed the two postulates of the attentional resources theory of intelligence, namely the decline in performance from single to competing conditions, and the higher correlations of these tasks with measures of intelligence when these tasks compete for pooled resources. This result held when the sample was divided into strategy users and non users, with the IT_2/IQ correlations becoming appreciably higher for strategy users. This suggests that strategy users became particularly dependent on general resources. One possibilty for this effect is that the dual task condition stretched the range of IT_2 scores, as shown by the increased mean and SD, and that *g* -related differences previously not separable became stretched onto a wider scale which exists when early information processing has to function with another task. Stankov's collapse model of dual task performance breakdown would appear to account for the results seen in the current study. Unfortunately, Stankov has since questioned whether 'attentional resources' has a strong link with intelligence (Stankov, 1989). He now argues that though parallel cognitive tasks have higher associations with measures of IQ than the simple cognitive tasks alone, the simple 'attentional resources' model does not fully account for this, as decrements in performance do not necessarily follow from the competing tasks. Rather, increases in *g* -associations under competing conditions may reflect processes not linked to attention, for example individual differences in cognitive strategy, the processing of complex stimulus features, or the efficient encoding of rapidly presented stimuli - all of which are seen in our study.

Though in principle this study has shown a range of intriguing results regarding the effect of attempting to disrupt the resources required for general attentional metastrategies during IT tasks, one should be cautious about strong extrapolations of the data; though the actual study was labour-intensive, the subject group was small (though no smaller than Mackenzie *et al*'s original study in 1985), and the numbers reduced further when the sample was divided into subjects reporting strategies or not. Interpreting a pattern of correlation coefficients between groups of 12 and 17 is unreliable, and it would be virtually impossible to have a statistically significant difference in correlations between two such small groups. There was also a very big increase in performance variability for IT_2, making the comparison of means across single and dual task conditions hazardous. A proper understanding of the current study may therefore require a replication with a larger sample, a parallel task which is not significantly correlated with IQ, a better understanding of the subtleties of attentional resource theory, and a consideration of how differences in mood may affect this procedure.

Does the perception and use of apparent motion cues during IT tasks have an appreciable delay associated with them? The subsequent study will attempt to operationalise apparent motion processes within IT trials using a measure of visual persistence, and will also measure the response latency taken for a subject to make an IT discrimination. If strategic processing is conscious and post-stimulus, the response latency for subjects who report apparent motion phenomenology during IT tasks should be significantly slower than individuals who do not report such phenomenology on the IT trials themselves. The possible difference in visual persistence of apparent motion reporters will also be examined, using a critical stimulus duration paradigm.

Chapter Five

Do cognitive strategies influence Inspection Time, Critical Stimulus Duration or Decision Time?

5.1.1. Introduction.

The current study examines whether individuals who report the use of apparent motion cues in IT tasks have; a) superior stimulus encoding on a comparable (but unmasked) task; and b) whether these individuals have a different pattern of response latencies within IT. The rationale for this derives from the contradictory nature of what we know about about IT-penetrating strategies. On the one hand IT-penetrating strategies are consciously reported, and appear to take advantage of the imperfect masking of some IT stimuli. On the other hand, individuals previously designated strategy users have faster ITs even when their consciousness is occupied by another task, and do not seem to be disrupted by false feedback. There is thus a possibility that what are ostensibly useful strategies are in fact 'pseudo strategies' - conscious awareness of epiphenomena.

If the reports of strategy use on IT are epiphenomenal to an information-processing difference that enables some individuals to perceive IT stimulus lines faster than others, then two results should follow. Firstly, other measures of perceptual speed should be faster for strategy users. Secondly, as the application of strategy takes time, the response latencies of epiphenomenally strategy-reporting individuals should not differ from non-strategy users for IT decisions. If both of these hypotheses are supported, one could argue that strategy use on the IT task is an epiphenomenon of a mandatory processing advantage, and individuals do not really have a "strategy": they simply store stimuli more readily at an iconic stage. If performance is strategy-driven, this should be marked by conscious caution in strategic execution, and such individuals should have longer response times to IT stimuli.

5.1.2. Backward masking and its criticisms.

The notion of controlling information intake speed by the use of backward masking paradigms followed from Sperling's report that visual information could be inspected even after the stimulus had been removed from vision (Sperling, 1960). The mechanism involved was assumed to be a short-term visual memory store - iconic memory. The technique of backward masking attempts to overcome this process by providing a second, non-informational stimulus (a 'mask') which interferes with an earlier informational stimulus before the informational stimulus has been transferred from the iconic storage (Neisser, 1967). The mask is thought to overwrite the icon set up by the previous image, and thus disrupting the flow of information from iconic storage.

The experimental approach to cognitive psychology, and the subdivision of mental processes into specific processing stages has been questioned, sometimes from within its own ranks. Neisser (1976) took to criticising his own, early work, and rejected the view that iconic memory had anything to do with ordinary perception. Haber (1983) also rejected the construct of iconic memory, suggesting that an "icon" was not only useless, but also detrimental to the normal flow of visual processing. This is because ordinary perception is rarely discontinuous, any more than our eyes and heads are motionless; all are in continuous flux to adapt to equally changeable events in the environment. As normal perception is not composed of discrete flashes of visual stimulation, any mechanism, real or assumed, that uses such information is not only unnecessary, but also irrelevant to normal perception (Mustillo, 1985).

5.1.3. Critical Stimulus Duration.

Whatever the outcome of these arguments, the information-processing approach to visual information processing found a ready niche within experimental clinical psychology. Performance deficits related to abnormal visual information processing have since been reported in the mentally handicapped (Liebkuman and Friedrich, 1972), and schizophrenics are deficient on both speed of visual information processing, and susceptibility to backward masking (Balogh and Merritt, 1985). The task which these studies have used is known as 'critical stimulus duration' (CSD).

CSD is the minimum stimulus duration required to achieve a predetermined criterion of accuracy in a visual discrimination task. It is used initially to minimise individual differences in the time taken to transfer information to an iconic level, prior to the manipulation of the stimulus interval between the CSD stimulus and the backward mask. CSD does not use backward masking, and is thus free of the apparent motion cues seen in IT tasks when the stimulus figure is overwritten by the mask. CSD difficulty is defined by the absolute brevity of the stimulus presentation, which starts at 1 msec, and moves upwards until the individual can reliably discriminate stimuli; differences of CSD presumably demonstrate differences in the rate at which information is transferred from iconic storage to the short term memory (Averbach and Cariell, 1961).

Saccuzzo, Kerr, Marris and Brown (1979) reported that mentally handicapped samples needed longer stimulus durations in order to make correct discriminations than matched groups of similar mental or chronological age. They refrained from defining precisely the limitation they observed, but suggested that the processing level involved could either be encompassed by the iconic level, or, given the doubt regarding the theoretical entity this represents, "input capabilities". Donald Sharp was more straightforward: he reported that CSD correlated with both IT and IQ (Sharp, 1984).

5.1.4. Apparent motion and IT.

Individuals who report apparent motion strategies during IT tasks appear to exercise a specific strategy attributable to poor masking of the IT stimulus. A task-specific strategy for certain types of IT does not exclude the possibility that IT measures the rate of information apprehension, but does place greater importance on the removal (or comprehension) of these sources of unexpected variance on IT tasks. Removal of a backward mask from an IT stimulus effectively converts IT to CSD. One hypothesis to account for this phenomena is that individuals who report specific strategy use on IT tasks also have faster CSDs than their strategy-free fellows. If this is true, then specific strategy users are inherently advantaged on visual speed of processing tests, and strategy reporting is but a conscious epiphenomenon of faster encoding by some subjects.

5.1.5. Response latency and IT.

The theoretical rationale for IT involves Vickers' "accumulator model" for discriminative judgement (Vickers *et al*, 1972). This model assumes that sensory representation of stimulation relevant to the required discrimination is accumulated over time as it enters the processing system. This accumulation occurs against a background of neural noise, accumulation proceeding as a sequence of discrete inspections, each contributing some quantity of information to the final decision. A decision is made when evidence for some outcome reaches a criterion, this criterion reflecting the degree of caution adopted by the individual for that judgement. The time taken to make this response is mainly determined by the level of caution adopted by the individual, along with his or her IT.

Considering this in relation to the problem of IT-penetrating strategies, one could hypothesise that an individual applying additional features (such as strategies) to the normal process of evidence accumulation would exercise more caution in his or her judgement. Brand (1985) has suggested that strategy users on IT tasks would have larger intra-individual standard deviations for IT performance across trials, because a strategy user would think more about his or her decision prior to his or her response. This would add a further stage of processing to the discrimination of IT stimuli, and, on implementation, delay the time taken to make the IT discrimination. Thus, the response latency of strategy-using subjects on IT tasks should be longer than for individuals who do not use strategies when they make their IT decisions.

Response times (RT) recorded during IT studies appear to reflect the decision making process described above; Lally and Nettelbeck (1977) observed that there were differences in the way that retarded and non-retarded adults responded to IT stimuli. For non-retarded adults, RT to correct responses typically becomes faster with decreasing duration of IT exposure, the RT becoming shortest at a duration around the individual's IT; error RTs are longer than those for correct responses. Retarded adults have similar RTs for both correct and incorrect IT responses, with little change across different IT exposure durations. This behaviour, suggesting that the response is almost an afterthought to the task, is known as "deadline responding", and could be equated with the individual having adopted a low criterion for responding. Nettelbeck (1987) suggests that this supports the view that retarded subjects take fewer samples when exposure speed is limited and makes discrimination ambiguous.

5.1.6. A specific processing stage in strategy users?

The most commonly reported (and demonstrable) IT strategy is that of using the apparent motion effect to signal the target stimulus on the side contralateral to the flash. This could be conceived as the following processing sequence:

STIMULUS -> perceptual intake -> discrimination -> RESPONSE

Individuals using an apparent motion strategy on the IT task presumably have an additional stage between the discrimination and the response, in which the identification response (press the key on the side the target stimulus was presented on) must be extended to incorporate a transfer of this response to the side contralateral to the side of the motion cue. This would take additional time, and distinguish apparent motion strategy reporters from those who do not use these cues during IT tasks. If the strategic process in IT involves metacognitive control, then, as the decision-making model also predicts, decisions prior to the IT discrimination will be slower for individuals augmenting their basic processing speed by an additional, planful process.

5.1.7. Identifying a strategic processing stage.

Donders (1868) proposed that the time to carry out a simple mental subprocess could be inferred by running a series of experiments that are identical in all respects, save that in the one the subject must use a particular process while in the other it is not used. Since then, many studies have attempted to decompose the various processing stages involved in mental operations (Posner, 1978). Gross subdivision of the IT task would presumably involve the following procedure; measuring the typical response latency for a simple, unmasked 2-choice visual discrimination at a long exposure duration; repeating this procedure, but using stimuli presented at very brief durations; then giving the same 2-choice visual discrimination a backward mask, and measuring the mean response latency for those IT trials at, or above, the IT of the subject. The increasing difficulty level of the different tasks could thus be quantified, and successive subtractions of the tasks from one another could isolate the processing stage involved in the inhibition and transfer of a response from one side to another. Strategy users would thus be expected to have a longer processing stage for transfer than strategy-free individuals for whom an IT task is one of simply detecting the target and making a response.

5.1.8. Hypotheses of this study.

Certain phenomena have been established by the studies within this thesis; the significant shortening of IT for subjects who perceive (and report) apparent motion on an IT task; the existence of IT/IQ correlations in both individuals who report strategies on IT tasks, and those who don't; and the equivalence of non-verbal IQ for these two samples. Strategy users do not have high IQ, extended practice on IT, vulnerability to false feedback, or any significant advantage in concentration or attention. The current study therefore examines a more basic hypothesis - that the reported apparent motion strategies are epiphenomenal to a more fundamental advantage strategy reporters have in early information processing. If the use of apparent motion on IT is a strategy, then process differences would only occur on tasks involving backward masking, apparent motion, and deliberate thought; if the difference is actually due to a lower process - superior iconic memory - then "strategy users" will have faster CSD, and equivalent response latencies for all tasks. The study thus considers the following hypotheses:

1) That individuals who report apparent motion strategies on the IT task will have significantly briefer CSD. (Indicating that the advantage reported on IT is because of their superior iconic memory.)

2) That individuals reporting strategies on IT tasks will take no longer to make their IT discriminations than individuals who do not report strategies. (Indicating that conscious deliberation regarding the locus of the IT target is no greater in "strategy"-reporting groups.)

3) That no RT difference can be isolated by the systematic decomposition of IT into different subprocesses. (Indicating that the "specific" additional stage reported by strategy users on IT tasks is an afterthought to their IT response.)

Support for these hypotheses would support the speed theory of IT, in which IT is considered to be nothing more than a measure of perceptual speed, and strategic explanations epiphenomenal to the underlying mechanism of *g* . Refutation of these hypotheses would suggest that higher-level strategic processes need to be considered by researchers using IT.

5.2. Method.

5.2.1. Design.

Individuals were counterbalanced regarding the experimental task they did first, and were retrospectively allocated into strategy or no-strategy groups according to their self-reports. The dependent variables were CSD, IT, the SPM and MHB, and the EPQ. The IT and CSD tasks recorded the RT latency for each task trial.

5.2.2. Subjects.

A total of 47 subjects were tested (24 male, 23 female). All were attending a Youth Training Scheme in Edinburgh. The psychometric data were collected at the training centre, with the experimental measures being given under controlled conditions in the Department of Psychology.

5.2.3. Equipment: Psychometric tests.

The SPM and the MHB (Form 1, Senior) tests of ability (Raven, 1962), and the EPQ (Eysenck, 1975) were given according to the instructions in their manuals. The SPM measured non-verbal IQ (*gf*). The MHB is a verbal test of synonyms, and measures verbal IQ (*g*c). The EPQ measures personality on 4 well-established dimensions; psychoticism (P); extraversion (E); neuroticism (N); and social acquiescence (L). In addition, a visual acuity test (the Snellen test) was given prior to the experimental session.

5.2.4. Equipment: Experimental tasks.

All experimental tasks were presented on a 7-segment LED display, with responses being made by pressing one of two hand-held response keys, as used in experiment 3 (see figure 4.2.i.). A pilot study found that the luminosity of the LED was such that CSDs rarely surpassed 2 or 3 msec, and that glare and reflected light affected the IT task. Thus, a blue filter was placed over the LED display to reduce the amount of unnecessary light emitted from the stimulus. The stimulus display was oriented vertically, with the overhead neon light remaining on and the laboratory window blacked-out. These factors controlled for reflected light and glare on the stimulus display. All subjects were seated approximately 36 inches from the display. A BBC microcomputer with RT, CSD, and IT programs controlled the LED display, (the LED display had been initially used for digital readouts, and was approx. 1.25 inches by 1 inch; see figure 4.2.i).

All experimental tasks followed the same initial routine, in which the subject was presented with a fixation-point, followed 250 msec later by a stimulus, after which the subject had to press the response key corresponding to the side the target stimulus was presented on. Each program waited until the response key had been pressed before recommencing. All tasks automatically stored four items of information from each trial; the exposure duration, the time taken to make the response (timed in hundredths of a second i.e. csec), whether the response was correct (or not), and the side of the target stimulus.

5.2.5. Simple discrimination RT (DISC-RT).

A simple RT to a two-choice discrimination task was derived by assessing the mean RT required for an individual to correctly discriminate the longer of two unmasked stimulus lines presented for 250 msec on 15 trials.

5.2.6. CSD.

The CSD algorithm presented subjects with stimuli at 1 msec exposures to start, the exposure duration increasing by 1 msec with each error. When the subject had 13 trials at a given duration correct, the program stopped, as a CSD had been derived. In each case the CSD trial was the same as that for an IT task, other than the lack of a backward mask. RT for CSD (CSD-RT) was the mean RT to the response times at an individual's CSD.

5.2.7. IT.

The IT task required that the subject discriminate whether the longer of two briefly exposed vertical lines was presented to the left or right of the LED display. This was followed immediately by a backward mask involving two vertical lines of the same length. The mask remained on the display until the subject made their response (the pressing of a left or right hand-held control). The stimulus sequence then returned to the beginning of the stimulus routine. The PEST algorithm was used to derive the IT measures (see section 2.2.3.3.). IT RTs were defined as the time between the onset of the stimulus figure and the pressing of a response key. Two versions of IT were administered. The first form involved the subject pressing a response button corresponding to the side of the stimulus that presented the longer of two lines (LIT). The second form involves the subject pressing a response button corresponding to the side of the stimulus that presented the shorter of the two lines (SIT). The corresponding RT measures for these tasks were LIT-RT and SIT-RT.

5.2.8. Procedure.

Prior to the experimental tasks, the subject completed the Snellen test of visual acuity; they were positioned 6 feet from the chart and were asked to read out the smallest line they could. Their visual acuity was the distance from the eye-chart divided by the shortest line read. Scores thus ranged from 1 to 3.

The subject was then introduced to either CSD or IT tasks, by means of an introductory demonstration program, the subject being told to press the response key corresponding to the side the longer line was shown on. If the SIT task was presented first, the target stimulus was the shorter of the two stimulus lines. In all cases subjects were told to work accurately, rather than quickly, and at their own pace.

Subjects were given full instructions regarding the 4 experimental tasks; the DISC-RT task was self evident, as the slow exposures ensured that direct feedback from the task was given. CSD began with brief exposure durations that were impossible for all subjects, and thus required a little more explanation. Subjects were told that they were going to be shown two lines at very quick speeds, and that their task was to press the button on the side of the longer line. They were told that the task started off very quickly, and they may not see anything to begin with, but they would soon find that the test would adjust to an exposure speed at which they could see the target lines. After any block of 5 correct discriminations, the subject was told "well done".

Instructions for IT differed slightly; subjects were told that they would be shown two lines, one much shorter than the other, for a short period of time, after which these would be covered by two lines of equal length. Their task was to press the button for the line that was on the longer (or shorter) side to start with. Subjects were told that the lines would be shown at differing speeds, but that for most of the time the lines will be shown at speeds they would find very easy to see. Subjects were reminded that the important thing was to be accurate, not to just press the button as fast as possible, and that the experimenter would tell them how they were doing on the task. Again, following 5 correct discriminations in a row, subjects were commended on their performance.

5.2.9. Strategy Elicitation.

While subjects were completing the IT tasks, the experimenter monitored their performance via a screen from the computer which provided a summary of their current performance. When this indicated that the PEST algorithm was at a step-size of 4 msec, and an appropriate natural break came into the task, subjects were asked to say how they were doing the IT task. The 'step-size of 4' criterion was chosen as it would be on the steep (difficult) component of the psychophysical function, and close to the stopping IT value. Subjects were asked to describe how they could see the difference between the lines when they were shown for such short durations. Generalisations from the subject were echoed in a Rogerian manner, and were followed by the enquiry "how does that help you?". This was to encourage a specific statement of any strategic process within the tasks. Those individuals unable to give a description of their task phenomenology were asked more directly: "Did you have any way that made the test easier to do when the lines were being shown quickly?". These responses were recorded.

5.3. Results.

5.3.1. General overview of the results.

Following the collation of the data, it was found that one SPM record form had been spoiled, and that two subjects had to miss the re-test IT condition. Data were pooled, then coded according to whether subjects reported using information derived from the backward mask in their IT discriminations or not. Subjects who met this condition were designated strategy-users. Thirty-two subjects reported strategy use to the SIT task, 29 on the LIT task, with 24 subjects using strategies on both tasks. Thirteen subjects did not report strategy use on the SIT task, 16 not reporting strategies on the LIT task; 11 individuals did not report strategy for either IT task.

Table 5.3.1. Correlation Matrix of experimental measures (n=47)

	MHB	CSD	LIT	SIT	Mean	SD
SPM	55 ***	-03	-44 ***	-28 *	38.9	9.5
MHB		-06	-45 ***	-29 *	21.2	4.0
CSD			42 **	49 ***	7.1	2.9
LIT				62 ***	39.1	24.4
SIT					33.6	13.5

(Decimal points dropped; significance values; * = P<.05; ** = P<.01; *** = P<.001)

Table 5.3.1. shows that both IT and IQ measurements correlated well with comparable measures (r 's respectively = 0.55 and 0.62, both P<.001). Mean (± s.d.) LIT was 39.1 msec (± 24.2 msec), mean SIT 33.6 msec (± 13.5 msec); though IT order was varied to control against putative order effects, nevertheless LIT was significantly longer than SIT (t = 2.82, P<.04). Mean CSD was 7.1 msec (± 2.9 msec). CSD correlated with the two IT tasks at about 0.45 (P<.01), but although the IT measures correlated with IQ (LIT/IQ r = -0.44, P<.01; SIT/IQ r = -0.28, P<.05), no such association was seen between CSD and the IQ measures (CSD/IQ r = - 0.05, n.s.). No correlation was found between either LIT and its corresponding number of trials (r =-.10, n.s.), or for the equivalent correlation on the SIT task (r =0.18, n.s.). Thus extended practice on IT tasks neither augmented or impaired IT performance.

5.3.2. The effect of strategy on the IT task.

The effect of strategy was considered in two ways; firstly t-tests were computed to compare mean scores on the experimental and psychometric measures for individuals reporting strategy (or not) on a single IT task. Secondly, individuals were coded according to whether they reported strategy use on both IT tasks, on one IT task, or on neither.

Though individuals who reported strategy use on the SIT task had significantly lower SIT than those who did not report any strategy ($t = 2.13$, $P<.05$), no other experimental or psychometric measure distinguished the two groups. Individuals reporting strategy use on an LIT task were also faster than those who claimed to do the task as instructed by the experimenter ($t = 2.10$, $P<.05$). These individuals were also significantly faster on SIT ($t = 2.39$, $P<.03$), and showed a trend towards a faster CSD ($t = 1.81$, $P<.09$), suggesting a more general iconic advantage. This group did not have higher IQs, or personalities that differed in any way from individuals who did not report strategy-driven IT responses.

Table 5.3.2 presents a summary of the experimental measures according to whether or not subjects used apparent motion cues during the LIT task. This shows that the standard deviations for CSD and LIT are significantly different, making assumptions about the homogeneity of variance between the groups questionable. Recalculation of these variables using the non-parametric Mann-Whitney test shows that CSDs do not significantly differ between strategy reporters and non-reporters (U = 196.5, W=506.5, $z = -1.356$, n.s.). This does not support the first experimental hypothesis, that individuals who report specific performance strategies on IT tasks have briefer CSD (and thus superior iconic memory) than individuals who do not report specific strategies. A similar non-parametric analysis shows that strategy users have faster LITs than non-strategy reporters ((U = 151, W=552, $z = -2.358$, $P<.02$).

The correlations between IT and IQ for individuals reporting strategy use (or not) within each IT task were computed independently. The LIT/SPM and LIT/MHB correlations for strategy reporters were -.46 ($P<.01$) and -.29 ($P<.07$) respectively. For non-strategy users the LIT/SPM and LIT/MHB correlations were -.56 ($P<.005$) and -.69 ($P<.001$). Using McNemar's formula for testing differences between correlations (McNemar, 1955), no differences were significant. Subdividing the SIT task according to strategy reporting or not showed SIT/SPM and SIT/MHB correlations of -.23 and -.12 (both n.s.) for non-users, and of -.25 (P<.09) and -.41 (P<.01) for strategy users. Again, differences in correlation were not significant.

Table 5.3.2. Mean (SD) of test variables divided by subject use of apparent motion cues during LIT.

	No cue		Cue users			Significance		
n	19		27					
	Mean	SD	Mean	SD	*t*	P<	F	P<
CSD	8.1	6.4	6.4	2.2	1.81	.10	2.60	.05
SIT	39.1	14.5	29.9	11.4	2.39	.05	1.63	n.s.
LIT	48.6	32.5	32.0	13.9	2.10	.05	5.48	.001
DISC-RT	397.0	236.0	269.0	139.0	2.10	.05	2.88	.05
CSD-RT	444.0	188.0	424.0	207.0	0.34	n.s.	1.21	n.s.
SIT-RT	503.0	245.0	452.0	197.0	0.73	n.s.	1.55	n.s.
SIT slope	-0.07	0.2	-0.08	0.2	0.12	n.s.	1.33	n.s.
SIT intercept	561.0	323.0	523.0	236.0	0.43	n.s.	1.87	n.s.
LIT-RT	636.0	343.0	609.0	466.0	0.23	n.s.	1.83	n.s.
LIT slope	-0.21	0.3	0.01	0.6	-1.63	n.s.	4.95	.001
LIT intercept	853.0	587.0	572.0	328.0	1.89	.10	3.21	.01
SPM	38.7	8.9	39.0	10.2	-0.11	n.s.	1.33	n.s.
MHB	21.9	4.9	20.7	3.9	0.90	n.s.	1.54	n.s.
P	5.6	3.1	5.3	3.0	0.41	n.s.	1.03	n.s.
E	12.7	4.7	14.1	3.6	-1.11	n.s.	1.71	n.s.
N	14.3	4.8	11.8	5.4	1.65	n.s.	1.30	n.s.
L	8.3	4.9	9.9	3.9	-0.76	n.s.	1.56	n.s.

(n.b. All t-tests one-tailed; all F values from the variance-ratio test (see text)).

Table 5.3.3. presents a summary of the mean (± SD) of the sample divided into groups repeatedly reporting, sporadically reporting or not reporting strategy use on an IT task. Differences across groups were tested with a 1-way ANOVA, with *post-hoc* Scheffe tests to conservatively test the significance of the mean differences observed. Only in the case of individuals reporting strategies on the SIT task was there a significant effect on an experimental task; no ability or personality measure showed any effect.

Table 5.3.3. Summary statistics (mean and SD) for subjects divided according to self-reported steady use, erratic use, or non-used apparent motion cues on IT tasks.

	No strategy		Some strategy		Steady strategy			
n	11		9		24			
	Mean	SD	Mean	SD	Mean	SD	F-ratio	P<
CSD	8.1	3.8	8.1	3.1	6.6	2.2	1.5238	n.s.
SIT	39.0	14.0	43.1	17.8	28.1	8.0	6.3450	.005
LIT	44.9	23.5	53.0	40.8	31.9	13.8	2.9629	.07
SPM	36.8	8.9	38.9	10.0	39.6	10.3	0.2941	n.s.
MHB	21.7	4.5	20.9	5.3	21.1	4.3	0.1036	n.s.
P	5.1	3.0	5.4	2.6	5.3	3.2	0.0380	n.s.
E	12.1	4.0	14.0	5.9	13.9	3.6	0.7856	n.s.
N	14.1	5.6	14.9	3.0	11.4	5.4	2.0648	n.s.
L	8.4	5.3	8.3	4.6	9.4	4.0	0.3141	n.s.

All comparisons across categories made with one-way ANOVA; post-hoc Scheffe tests show that the difference in means for individuals always and sometimes using strategies on SIT are significantly (P<.05) different. No other comparisons are significant.

Table 5.3.4. presents the correlation coefficients between the experimental variables according to steady, erratic, and non-strategy use. The pattern of correlations within the different subgroups repeat previous results, with the experimental and IQ measures correlating with themselves in the positive direction, and correlating with one another negatively. Within the subgroups, however, the significance of these associations was dependent upon the size of the sample, leading to many high, but statistically non-significant relationships.

Table 5.3.4. Correlations between experimental and IQ measures, for groups reporting constant, intermittent, or no apparent motion strategy use.

	Strategy use					
	No strategy		Some strategy		Steady strategy	
n	11		9		24	
SPM/MHB	59	*	70	*	52	**
CSD/LIT	03	n.s.	79	**	18	n.s.
CSD/SIT	52	*	53	n.s.	30	n.s.
LIT/SIT	39	n.s.	68	*	62	**
CSD/SPM	32	n.s.	-12	n.s.	-15	n.s.
CSD/MHB	39	n.s.	-53	n.s.	-12	n.s.
LIT/SPM	-82	***	-39	n.s.	-42	*
LIT/MHB	-44	n.s.	-76	**	-35	*
SIT/SPM	04	n.s.	-43	n.s.	-43	n.s.
SIT/MHB	-09	n.s.	-47	n.s.	-44	n.s.

(Decimal points dropped; significance * =P<.05; ** =P<.01; *** =P<.001.)

5.3.3. Response latency within IT tasks.

Individual RT data points were reduced by tabulating the accuracy of the perceptual discrimination against the exposure duration, and keeping the RT values for those exposure durations equal to, or above the IT observed. RT values for correct responses were converted into mean RT latencies for the different exposure durations used for each individual. The mean of these means was used as a static RT measure. To produce an RT value that reflected the dynamic nature of the IT-RT, these RT row means were correlated with their corresponding exposure durations, and converted into regression lines, the slope of which represented the rate of change in RT with increasing difficulty of IT discrimination (see figure 5.3.3.i.).

5.3.4.The difficulty of experimental tasks within groups

The interpretation of results from subjects sporadically reporting strategies on on IT task or another makes summarising data difficult; thus the results below either correspond specifically to the task described (SIT or LIT), or to those subjects who consistently reported (or did not report) strategies.

The difference between the DISC-RT and the CSD-RT tasks represents the slowing of the decision process with increasing task difficulty. Irrespective of whether one considered the full sample, strategy users, or non-users, the difference between the two unmasked tasks was significant (t = -3.73, P<.001; t = -4.40, P<.001; t = -2.38, P<.05) respectively. Again, irrespective of whether one considered the full sample, or divided them into strategy users or non-users, the increase in difficulty from CSD-RT to SIT-RT was non-significant (t's respectively -1.54, -1.28, and -1.89). The LIT task resulted in longer RTs than CSD (CSD-RT vs. LIT-RT t = -3.50, P<.001) for the full sample, for strategy users (t = -2.11, P<.05), and for non-strategy users (t = -1.89, P<.08). Although the overall comparison of response latencies for LIT and SIT showed a significant difference between the tasks (t = 3.04, P<.01), this difference

a) Percent accuracy of IT discriminations to differing exposure speeds.

b) Percent accuracy plotted against mean correct IT response time.

c) Exposure duration of IT plotted against mean correct IT response time.

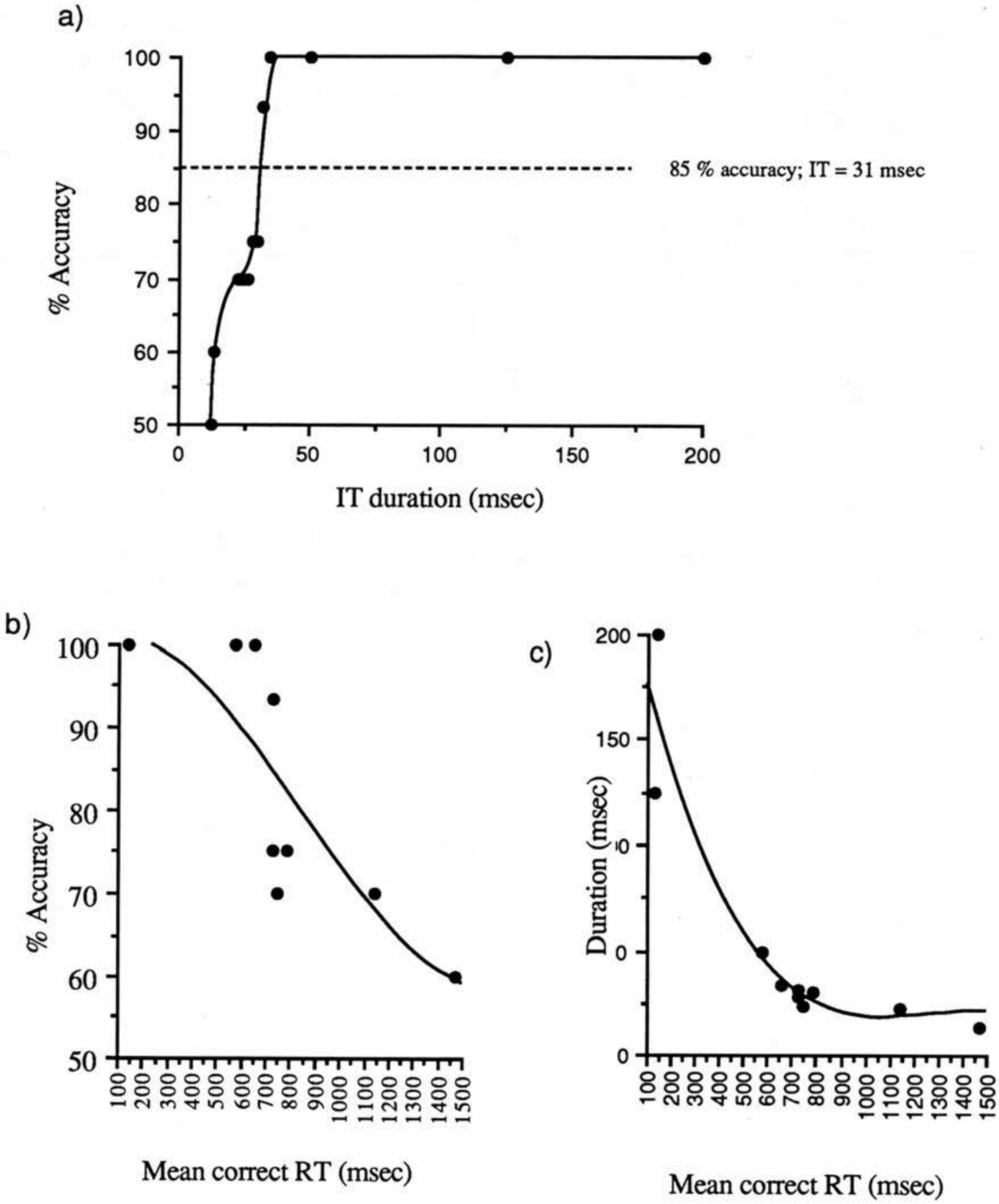


Figure 5.3.3.i. Data for subject 1. RT data plotted against IT performance.

reduced to a trend for both strategy users and non users (LIT-RT vs. SIT-RT *t*'s respectively 1.84 and 1.74, both P<.10). Thus difficulty for all tasks was equivalent within strategy using (or non-using) groups.

5.3.5. Comparison of RT data for LIT strategy users and non-users.

Comparison of those subjects who reported strategies on the LIT task with those who did not found that strategy users took less time to make their decisions on the DISC-RT task (*t* =2.17, P<.04). Neither CSD-RT, SIT-RT, or LIT-RT differed significantly between the two groups. This supports hypothesis two; that individuals reporting specific strategies on IT tasks will not take any longer to complete IT discriminations than individuals who do not report strategies. Equivalent analysis for subjects who reported strategies on the SIT task found similar response latencies to non-strategy users for the experimental tasks, though strategy users had a significantly smaller standard deviation for SIT-RT (variance-ratio F-test = 2.55, P<.04). The LIT-RT slopes for LIT strategy users were compared to the slopes for LIT non-strategy users; though the difference between the groups was non-significant (*t* = -1.63, n.s.), the mean (±SD) slopes were 10 (60) and 210 (30) msec for strategy users and non-users respectively. The difference in SD was significant (variance ratio F-test = 4.95, P<.001). Mean LIT-RT intercept values for strategy users were 570 (330) csec compared to 850 (590) csec for non-users (*t* = -1.89, P<.10). The SD values were significantly different (variance-ratio F-test = 3.21, P<.01).

Mann-Whitney tests for those variables with significantly different SDs found no difference for CSD-RT between strategy users and non-users (U = 234, W = 469, *z* = -0.502, n.s.). Nor was there a difference between LIT slopes (U = 190, W = 380, *z* = -1.485, n.s.). The LIT intercept was significantly lower for strategy reporters (U = 167, W = 536, *z* = -1.997, P<.05). A similar analysis for individuals using strategies (or not) on SIT found no differences between the two groups for slopes or intercepts.

5.3.6. Subtracting latencies to isolate processing stages.

Table 5.3.5. Summary RT statistics (mean and SD) for subjects divided according to whether subjects never, ever, or consistently reported strategies on IT tasks (values in msec).

	No strategy		Some strategy		Consistent strategy			
n	11		9		24			
	Mean	SD	Mean	SD	Mean	SD	F-ratio	P<
DISC-RT	377.0	241.0	400.0	262.0	272.0	141.0	1.8029	n.s.
CSD-RT	478.0	220.0	414.0	192.0	415.0	202.0	0.3914	n.s.
SIT-RT	666.0	408.0	552.0	236.0	608.0	490.0	0.6121	n.s.
LIT-RT	545.0	296.0	403.0	137.0	466.0	196.0	1.0860	n.s.
A	101.0	141.0	28.0	260.0	138.0	150.0	2.7331	.08
B	59.0	222.0	99.0	316.0	37.0	109.0	0.3261	n.s.
C	-42.0	282.0	141.0	396.0	-105.0	155.5	2.8828	.07

A = the mean difference between CSD-RT and DISC-RT; B = the mean difference between the SIT-RT and LIT-RT tasks; C = the mean difference between subtracted variables B and A.

All comparisons across groups with one-way ANOVA, with *post-hoc* Scheffe tests to compare means; n.s. = non-significant.

To isolate the inferred additional processing stage required for a strategy-driven IT discrimination, the RTs for the different experimental tasks were subtracted from one another. CSD-RT minus DISC-RT theoretically represents the slowing of decision processes when a simple discrimination is conducted at the edge of an individual's perceptual threshold. The LIT-RT minus SIT-RT variable represents the change of RT for IT tasks that have different target lines. The subtraction of the CSD difference from the IT difference represented the overall change in RT across all tasks. One-way ANOVA compared the 3 strategy groups (no strategy, some strategy, consistently applied strategy) on these three variables and found trends to significance ($P<.1$) for the increasing difficulty of the simple discrimination with faster exposure speed, and the net effect of subtracting this simple discrimination difference from the difference in IT latencies. No significant difference in RT to different tasks was seen across strategy classifications, so supporting hypothesis 3, that no RT difference can be isolated between strategy users and non-users attributable to a specific additional processing stage in specific strategy users.

Table 5.3.6. presents correlations between IQ and RT measures for the full sample, and for those individuals consistently, sporadically, or not reporting strategy use on the IT task. They show that the IT-RT measures quite reliably correlate significantly with one another. By contrast, of the 32 correlations calculated between RT and IQ measures, only 2 are significant ; these are probably due to the number of correlation coefficients calculated to start with.

Table 5.3.6. Correlations of RT and IQ measures for the full sample, and subdivided into individuals never, sporadically, or consistently reporting strategies on the IT task.

					Strategy use			
	All subjects		No strategy		Some strategy		Constant strategy	
n	44		11		9		24	
DISC-RT/CSD-RT	60	**	82	**	30	n.s.	68	**
DISC-RT/SIT-RT	55	**	77	**	24	n.s.	57	**
DISC-RT/LIT-RT	46	**	81	**	13	n.s.	50	**
CSD-RT/SIT-RT	64	**	87	**	66	**	51	**
CSD-RT/LIT-RT	48	**	59	*	69	**	40	*
SIT-RT/LIT-RT	73	**	83	***	75	**	71	***
DISC-RT/SPM	-06	n.s.	09	n.s.	-14	n.s.	-07	n.s.
DISC-RT/MHB	-11	n.s.	16	n.s.	-21	n.s.	-33	n.s.
CSD-RT/SPM	-17	n.s.	12	n.s.	-06	n.s.	-22	n.s.
CSD-RT/MHB	-08	n.s.	16	n.s.	-66	**	-05	n.s.
SIT-RT/SPM	00	n.s.	21	n.s.	-04	n.s.	-05	n.s.
SIT-RT/MHB	-10	n.s.	12	n.s.	-48	n.s.	-19	n.s.
LIT-RT/SPM	-22	n.s.	24	n.s.	-35	n.s.	-36	n.s.
LIT-RT/MHB	-20	n.s.	35	n.s.	-77	**	-32	n.s.

(All decimal points dropped, statistical tests for one-tailed comparison. Significance; * = P<.05; ** = P<.01; *** = P<.001.)

5.4. Discussion.

The current study enquired whether the superiority of apparent motion reporters on IT tasks attributable to their advantage on comparable (but unmasked) visual discrimination tasks. It also examined whether this strategy-driven IT performance was apparent from their longer response duration prior to putative IT discriminations. In each case there was mixed evidence; though there was a trend towards differences between strategy users and non-users on the LIT task, there was no difference between these groups for SIT. Combining data from both IT tasks obscured these effects due to the inconsistent application of strategy by some subjects. Given this reservation, results from the study showed little support of the first hypothesis, that strategy-reporting individuals have superior early information-processing speed prior to strategy execution. There was support for the second hypothesis, that strategy-reporting individuals would not take longer to make their decisions prior to an IT discrimination (though strategy users appeared to be faster at making a simple 2-choice discrimination, and showed much more variability in their LIT performance). The third hypothesis, that no additional processing stage specific to the IT-penetrating strategy would be identified was also confirmed; individuals found the tasks increasingly difficult (as shown by their RT latencies), irrespective of strategy use or not, this difficulty increasing at the same rate of magnitude for both groups.

A visual IT task involving the identification of the shorter stimulus line was significantly easier to identify than a complementary task, in which the target stimulus was the longer line. This may be because SIT is more a detection task, than one of discrimination, and is thus correspondingly easier. Individuals who reported the use of apparent motion cues to make their IT discriminations could not be identified by their superior IQs or particular personality characteristics. IT, in particular LIT, correlated with IQ measures at - 0.44 ($P<.01$). Stratification of the sample by self-reported strategy did not change this IT/IQ association for the more difficult IT task. Unmasked perceptual discrimination did not correlate with IQ. Covert measurement of RT data coupled to the perceptual discrimination tasks was analysed, and compared across strategy samples. Though RT increased with the increasing difficulty of the discrimination tasks, there were no significant differences in mean RT to the different tasks. Subtraction of the different RTs to identify a specific processing stage for the transfer of a response from one side to another did not isolate an additional operation in the response sequence of the strategy user.

The RT model used in this study assumed systematic additive processes in mental operations, the independent insertion of additional stages under certain conditions, and the statistical independence of the times of the different stages; all of these assumptions are questionable (Luce, 1986). The parallel processes underlying apparent motion (Dick, Villman, and Gagi, 1987) are not directly amenable to investigation using subtractive techniques intended for serial mechanisms. However, certain features did emerge regarding the responses of strategy users; strategy users had more restricted variation in their RTs as compared to individuals who did not report strategies on the LIT task. Strategy users on the LIT task had lower DISC-RT to start with. DISC-RT simply involved measuring the time taken for a subject to correctly discriminate an unmasked IT stimulus presented for 250 msec, and was thus of minimal difficulty. That LIT-related strategy users had faster DISC-RT than LIT-related non-strategy users perhaps suggests faster decision making in strategy users, or, even more attractive to general critics of IT, better 'response organisation'. A consideration of the other RT data reported does not support this; strategy users may, on one task, have briefer RT. However on all other tasks the differences were non-significant. This could have been because of the gross nature of the RT mean. The fit of the linear function between RT and different IT durations was not ideal, and subsequent studies might consider more trials at durations around an individuals' IT, and either logorithmic transformation of this skewed data, or line fitting using curvilinear functions. Given these shortcomings, the measures of RT dynamics within IT suggested that the rate of change was lower for strategy users as compared to non-users. This provides some non-introspected evidence of strategy reporters on an IT task, as it implies that strategy users are not finding the IT task increasingly difficult with reducing exposure durations.

One problem in this study was the use of a PEST algorithm to derive IT. Though PEST is quick, well-validated, sensitive to individual differences, and computes psychometric curves specific to an individual's performance, this technique gives individuals different numbers of exposure durations. It was therefore not possible to compare the same individuals, stratified by strategic self-report on their RTs to the same set of different IT exposure durations - a technique that Wilson and Nettelbeck (1986) used to assess the effects of age and ability on IT response times. The paradigm of responding time (Kirby and Nettelbeck, 1991) may provide a more appropriate research method for examining RTs within IT tasks.

The CSD task was administered in keeping with the paradigm . However, the blue filter placed over the stimulus, intended as a constraint on superfluous stimulus luminousity, may have constrained the task, making it vulnerable to subtle differences between individuals in visual sensitivity. Whatever the limitations of the CSD task, it did establish perceptual and decision time baselines prior to the introduction of the IT tasks, and helped establish that visual persistence does not explain why some subjects report using apparent motion cues during IT.

This study replicated previous results regarding IT, IQ, and cognitive strategies; IT correlated with IQ irrespective of strategy or not; strategy reporters had faster ITs than individuals who did not identify a performance strategy; and strategy users and non-users had equivalent IQs. The discovery that SIT was significantly easier to identify than the LIT target was unexpected; in principle, the two tasks were identical, and the counterbalanced order of administration should have ensured that any effect of practice was controlled for. The best explanation is that the SIT stimulus was too simple, making SIT a task of detection rather than comparison. Subsequent IT tasks should consider the use of bigger stimuli, with longer, fully-overwriting backward masks to make apparent motion effects less obvious.

Though significantly faster IT s among strategy using subjects could mislead the tester unaware of strategic possibilities, there is no evidence of a disrupted IT/IQ r. These results suggest that the IT process is affected, but not the IT-IQ relationship as such: strategy-users have a normal IT, but it is augmented by the use of apparent motion cues. The problem of apparent motion within the IT task is not one of superior visual persistence in the strategy user, and the lack of strong response time effects suggest that the use of apparent motion strategies is not due to conscious deliberation, as otherwise the response times to strategy users would be slower than for non-users.

Jerry Fodor notes that the central processing systems of our minds have only limited access to the computational processes that occur within the parallel, hierarchical input systems of our sensory apparatus (Fodor, 1983). These input systems have the advantage of being fast, mandatory, and relatively uninterrupted by parallel tasks. The short-range apparent motion perception seen on IT tasks possibly reflects the access by some individuals to computational processes within ostensibly "encapsulated perceptual modules". Fodor jokes that "..the ghost has left the machine, but has not been exorcised..", alluding to the redundancy of dualist explanations of mental processes in the emerging world of computational neuroscience, and naive materialism's inability to account elegantly for complex conceptual thought. Something similar is apparent in IT studies; though the vague objections of generalised strategy "theory" do not account for strategic effects within IT, a systematic, possibly epiphenomenal "strategy" is seen in some subjects. There is an unexorcised ghost in the g machine.

Chapter Six

Conclusions.

This thesis considered the relationship between intelligence and IT, with special reference to whether the IT/IQ phenomena could be explained by differing IT-strategies among testees of differing IQs. The four experiments of the thesis examined different aspects of strategic processing, with the studies becoming increasingly specific about the particular process theorised to occur during IT or strategy execution.

6.1. A summary of the results from experiments 1 to 4.

6.1.1. Experiment 1.

Metastrategic theories hold that the higher IQ subjects have strategies that are both more effective, and more general, than individuals who do not use strategies (Butterfield, 1986). Experiment 1 thus looked at the possibility that strategy users on IT tasks have some general 'metacognitive' advantage on IT tasks. This was taken to mean some overall conscious approach to a series of tasks that ostensibly require quite different responses to perceptual discrimination, for example, in the broadest sense of the term, 'attention'. With this intention, subjects were tested on auditory, two-line, and alphanumeric variants of the IT task. The only IT task vulnerable to strategies was the two-line visual IT task; subjects were divided into groups using attentional, apparent motion, and no strategy on this task. Though there was a significant difference on a two-line visual IT across groups, controlled *post-hoc* comparisons between the subgroups found no significant differences between pairs of means. There was no difference between these subgroups on measures of IQ. An IT task using alphanumeric stimuli generated a significant negative IT/IQ correlation; this correlation was also found within each subgroup when the sample was divided into strategy and non-strategy reporting subjects. The previously noted significant correlation between auditory IT and IQ was not replicated. The results were taken as meaning that general metastrategic theories have little to contribute in the debate regarding strategic effects on the IT task.

6.1.2. Experiment 2.

Experiment 2 examined the effect of false feedback and task difficulty on IT-strategy users, on the grounds that the development and application of useful strategies is dependent upon feedback from a task. Subjects were given an IT task (ADIT) that started at a minimal exposure duration, and increased in 1 msec steps, until the subjects found that they could reliably discriminate the IT stimulus lines. To make this IT task even more difficult, subjects were given either truthful or false feedback from the task. This was done with the intention of making the IT task particularly difficult for individuals who were attempting to develop and refine an IT-related strategy. It was found that there was no difference between ADIT and a more conventional IT task, and that they correlated significantly with one another. The study also found that there was no difference between subjects who were given either truthful or false feedback on the ADIT task. This suggested that feedback was irrelevant to the phenomenological reports given during IT tasks. Neither IT task correlated with measures of IQ; possibly because of the restricted IQ variance in the student sample. Individuals who reported strategies were not significantly higher in IQ than those who did not report strategies.

These first two experiments were conducted on populations of University students, using computer monitors to present ITs, and written self-reports of strategies. It was decided that these features prevented a proper examination of the problem on the following grounds; University students have restricted IQ variance; computer monitors do not expose IT stimuli for the precise durations specified by the psychophysical algorithms; and group-tested subjects cannot be relied upon to write down performance introspections during a task. The subsequent studies therefore used an LED device to expose ITs at precise durations, using samples of low to normal ability, in individualised test situations, where strategic processes could be elicited during the task.

6.1.3. Experiment 3.

The third study looked at IT using a dual task paradigm. This was to examine the extent to which IT was dependent on attentional resources, and whether IT-penetrating strategies involving apparent motion cues were due to greater amounts of these resources. Subjects completed IT alone, and in parallel with PASAT. PASAT correlated highly with IQ, and was so consciousness-consuming that no strategies were spontaneously reported during the dual task condition. Though ITs for individuals who previously reported the use of apparent motion cues on the secondary IT task tended to remain shorter than for those individuals who did not report apparent motion cues, this result was not statistically significant when IT was performed in conjunction with PASAT. This was possibly because of the significantly greater variability of dual-task IT performance among those subjects previously defined as not using motion cues. The study found that IT correlated significantly with IQ and PASAT for strategy users, but that strategy users did not have higher IQ or PASAT scores than non-strategy users. These results were interpreted as evidence that the use of apparent motion on IT tasks is not a strategy in the general sense of the term, as it is not dependent on conscious processing, and is not more common in higher-IQ subjects. The results of this small study also suggested that IT indexes resources more strongly in strategy users than non-users.

6.1.4. Experiment 4.

The fourth study looked at the response latency of IT and IT-like tasks, on the grounds that strategic processing associated with the registration and response of apparent motion cues may have a time lag associated with their execution. A Donders-type study was conducted, but did not isolate a specific strategy processing stage for individuals who reported using apparent motion to guide their IT discriminations. Nor did static measures of RT within IT discriminate strategy users from non-users. However, dynamic measures of RT within IT, based on the regression line describing the change of RT with increasing difficulty of IT, tended to be faster for apparent motion reporters. These individuals were not advantaged on an unmasked version of the IT task. IT/IQ correlations were found, irrespective of whether the subjects reported the use of apparent motion on IT or not, no difference being seen between these two groups on measures of IQ or personality. The results of the experiment were taken as evidence against the idea of a specific information-processing stage associated with strategic operations.

6.2. Pooling the results from experiment 3 and 4.

The results of experiment three and four involved the same apparatus, a low to normal IQ sample, and relatively reliable 'strategic' reports. The IT, IQ and personality data were pooled to form a sample of 75 subjects, 31 of whom did not report using apparent motion cues, compared to 44 who did. The combined results are seen in table 6.2.1.

Table 6.2.1. shows that the correlation between IT and the SPM is at the same approximate magnitude to that between IT and the MHB: $r = -.39$ ($P<.01$). This suggests that the IQ variance accounted for by IT is equally split between measures of g f and g c. Modest associations between IT and the personality dimensions of P (psychoticism) and L (social acquiescence) can also be observed.

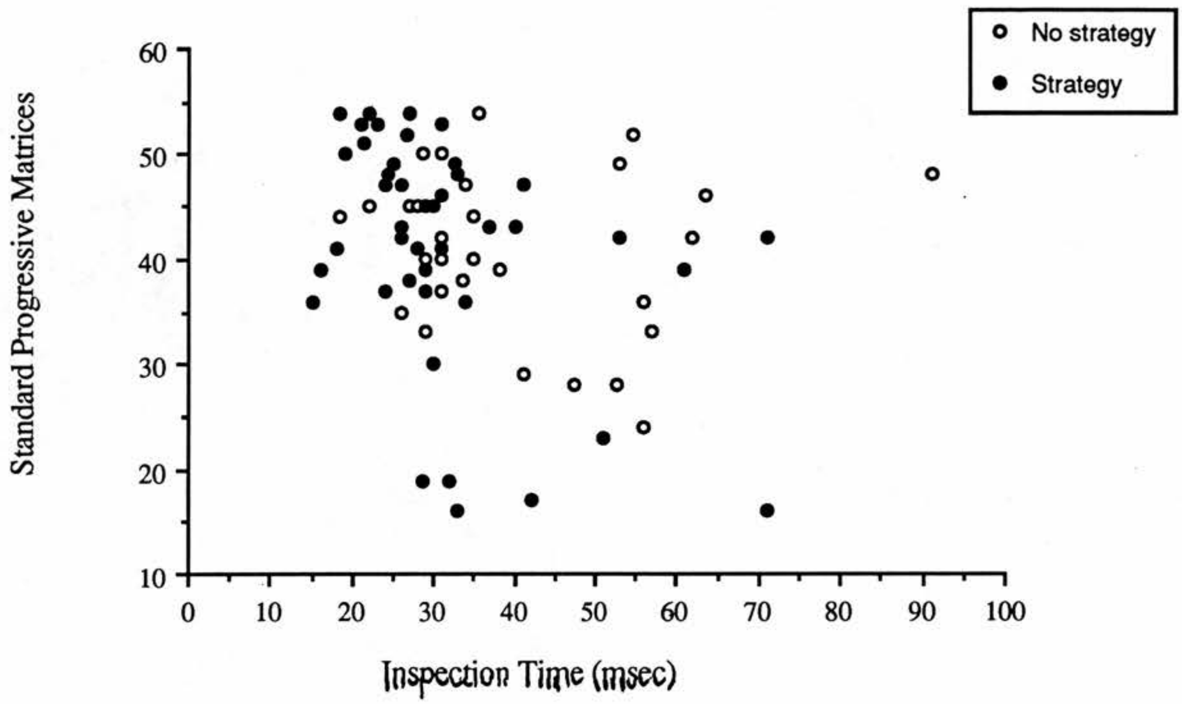
Table 6.2.1. Correlations between IT, IQ and EPQ variables for the full sample. (n = 75)

	SPM	MHB	P	E	N	L	Mean	SD
IT	-39 **	-37 **	26 *	-07	15	34 **	37.3	20.9
SPM		63 **	-18	00	-20	-48 **	40.5	10.2
MHB			-13	04	-07	-54 **	23.3	5.2
P				14	01	-13	5.0	3.3
E					-13	-20	14.0	4.1
N						-06	12.5	5.5
L							8.3	4.8

(Decimal point dropped, significance; * = P<.05; ** = P<. 01.)

The association between IT and L (r = 0.34 (P<.01)) may be partially attributable to the nature of the population tested; a low-to-normal ability sample, in whom the L scale is effectively a measure of IQ in the social domain (Egan, 1989). To test this possibility, the correlation between IT and L with the SPM or the MHB partialled-out was computed; in each case the result was the same: r = 0.18 (n.s.), confirming that the IT/L correlation was, in essence, an IT/IQ correlation. IT/IQ correlations were recomputed for subjects who reported the use of apparent-motion phenomena during IT; the revised IT/SPM and IT/MHB correlations were -0.44 (P<.01) and -0.26 (P<.05), respectively. IT/SPM and IT/MHB correlations for individuals not using apparent motion cues to guide their IT discriminations were -0.44 (P<.01) and -0.53 (P<.001). Thus the IT/IQ correlation held for both populations, irrespective of whether strategies were reported or not. Scattergrams indicating the correlation coefficients between IT and IQ measures are presented in figure 6.2.i. A comparison of the scores on IT, IQ and personality tests for strategy users and non-users is presented in table 6.2.2, which follows the figure.

a) IT with the Standard Progressive Matrices (2 outliers excluded).



b) IT with Mill-Hill Vocabulary Test (part B) (2 outliers excluded).

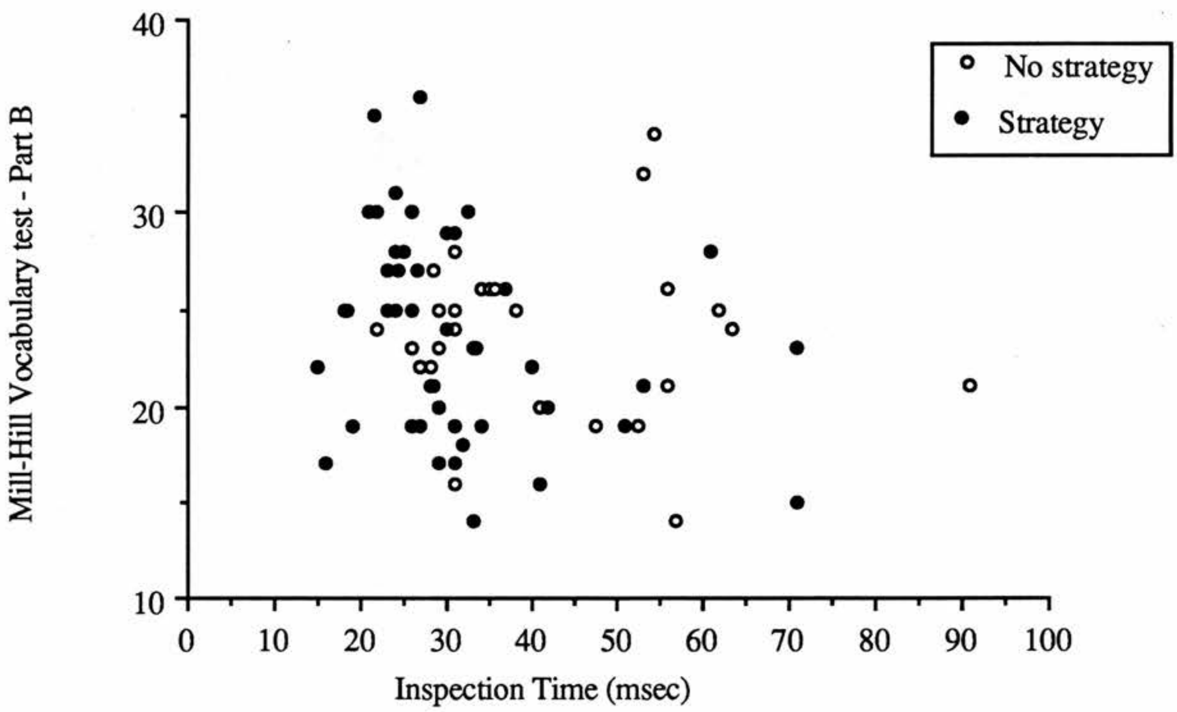


Figure 6.2.i. Overall IT/IQ correlations, subdivided by use of apparent motion cues or not.

Table 6.2.2. T-tests comparing subjects who use apparent motion during IT with those who do not.

	No strategy		Strategy users		Significance			
n	31		44					
	Mean	SD	Mean	SD	*t*	P<	F	P<
IT	46.0	26.8	30.7	12.4	2.97	.005	4.70	.001
SPM	39.5	9.3	41.1	10.9	-0.72	n.s.	1.38	n.s.
MHB	23.1	4.9	23.6	5.4	-0.39	n.s.	1.22	n.s.
P	5.2	3.3	5.0	3.3	0.28	n.s.	1.01	n.s.
E	12.9	4.6	14.7	3.6	-1.77	.08	1.63	n.s.
N	14.0	4.7	11.4	5.8	2.19	.04	1.54	n.s.
L	8.4	4.7	8.1	4.7	0.26	n.s.	1.02	n.s.

(Mean comparisons made by independent subjects *t* -test, SD comparisons by variance-ratio F test.)

Table 6.2.2. shows that individuals who report using apparent motion cues during IT performance have significantly faster IT than individuals who report doing IT by comparing line sizes (t = 2.97, P<.005). The performance of strategy reporters is significantly less variable than that of non-reporters (variance-ratio F-test = 4.70, P<.001). A test of these ITs using a non-parametric statistic strengthens the difference between strategy users and non-users (Mann-Whitney test U = 349.5, W = 1510.5, z = -3.5801, P<.0003). The effect size of strategies on IT was 1.25; thus, the average user of apparent motion cues during IT was advantaged by one and a quarter standard deviations relative to a sample combining strategy users and non-users. By contrast, there were no IQ differences between the two groups, either on average, or in terms of variation of scores. There was some suggestion that strategy users differ from non-users on measures of personality; non-strategy users had significantly higher N

(neuroticism) scores than strategy users (t = 2.19, P<.04), and showed a trend towards greater introversion (t = -1.77, P<.08).

6.3. Future avenues for research on IT and apparent motion.

The studies conducted in this thesis attempted formally to examine the predictions made by strategic theorists. These predictions were derived from multiple-level models and cognitive theories which often provided little by way of objectively testable hypotheses. It is therefore possible that the hypotheses examined do not correspond to the current reasoning regarding strategic processes. This shortcoming could be easily overcome by having proponents of strategies say more precisely how low level feature extraction speed (which is effectively all that IT is) corresponds to higher thought. Until better theories of IT-related strategic processes emerge, metastrategic theories should consider themselves unproven. However, despite the ineffectiveness of strategic theories to account for apparent motion phenomenology during visual IT tasks, the task-specific effect of perceived apparent motion on IT was both confirmed and quantified. Further research is thus required to understand this phenomena. These should take approaches from visual science, psychophysiology, and experimental psychology.

6.3.1. Visual science studies.

Korte's laws (see Gregory, 1987) refer to the types of apparent motion elicited by alternately switched lights, and detail the time intervals and separations of alternating pairs of stimuli necessary for optimal apparent motion effects. Of the five kinds of apparent motion described, two are particularly relevant to the phenomenology reported within IT tasks; ϕ movement - in which the phenomenology is of pure motion, and α movement, in which subjects report the movement as a transient change in size. A study of the individual differences in these processes in relation to IT, intelligence and personality may clarify the nature of the apparent motion perceived during visual IT tasks. (It may also account for why experiment 3 went against the established relationship between motion after-effects and extraversion.)

The experimental literature on apparent motion provides a range of manipulations and psychophysical axioms with which to investigate the effect of specific strategies on IT. Working hypotheses could include constraining stimulus luminosity; manipulating the spatial frequency of the IT stimulus lines; changing the direction of movement; and manipulating the movement velocity of the apparent motion cue (Irvy and Cohen, 1990; Werkhoven, Snippe and Koenderink, 1990). The derivation of IT shows that subjects are able to perceive visual stimuli despite being presented with stimuli at rates faster than their saccadic eye movements can adjust to. This suggests that some individuals have enhanced perceptual faculties for stimuli *within* fixations. Julesz (1980) has advanced the concept of 'textons' - discriminable textures with specific two dimensional features that exist as conspicuous local features of a target, rather than products of global visual processing. He suggests that pre-attentive visual processes inspect an image in a parallel fashion, and detect changes in the kind and density of textons.

In relation to the IT task, a single texton change at the point where the mask overwrites the shorter stimulus line possibly makes the subject aware that the longer stimulus line is logically on the other side. If the texton theory is correct, then one solution to the problem of texton cues may be to reduce the redundancy of the IT stimulus, in which the texton can be in one of two places, and replace it with a busier mask in which motion occurs in many places simultaneously. The increase in visual information would thus change texture throughout the stimulus display. Though discrimination of two dichotomous stimuli would still occur, the texton detection system would be overloaded. This would make the single apparent motion cue inapplicable, and remove the problem of task-specific apparent motion effects from IT tasks that rely on two vertical lines.

6.3.2. Psychophysiological studies.

A study to elucidate the point at which apparent motion-guided IT discriminations occurs should be conducted by coupling an average evoked potential (AEP) to IT stimuli for apparent motion reporters and non-reporters. Zhang, Caryl and Deary (1989) report that the rise time of the P200 AEP component ($P200_T$) especially correlates with IT, with P200 being particularly associated with the transfer of information from sensory buffers to short term memory (Chapman *et al*, 1978). If the awareness of apparent motion cues occurs after IT discrimination, then the $P200_T$ for individuals using apparent motion cues will not be associated with IT to the same degree, and later AEP components will become more prominent. If the perception of apparent motion is made at an earlier point in the apprehension of the stimulus, the amplitude of earlier AEP components may be higher.

6.3.3. Experimental studies.

The IT tasks used in these studies were not ideal; further IT studies should use either tachistoscopes, rapid-refresh computer monitors or densely-packed LED matrices to present IT stimuli - all of which should minimise obvious apparent motion effects. This proposes two very straightforward studies of strategic effects within IT; an investigation of the various technologies used to present the IT stimuli in the first place, and a study of the different types of masking stimuli possible. It has yet to be demonstrated whether strategic effects are more common with computer monitor screens, degraded LED displays, or tachistoscopes. If it is the case that all devices are similarly affected by strategies on IT tasks, then one should proceed to investigate the formal psychophysical features of such apparent motion perceptions. If it is the case that certain devices are strategy-free, then time, money and effort would be more usefully employed in researching IT with those particular devices.

6.4. Broader issues relating to these results.

Whatever the science of apparent motion, general reference to 'strategies' remain the most popular objections to IT. Though this thesis has established that it is possible to address empirically strategic issues in relation to experimental measures of perceptual intake, it is questionable whether *any* kind of objective test or treatment of strategic ideas in relation to measures of information-processing speed actually convinces critics of the IT task. It is even unclear whether the term 'IT' has entered the psychological lexicon for researchers with a special interest in intelligence. A case in point is a recent editorial in the specialist journal 'Intelligence'. In this article Stephen Ceci discusses "..the relation between microlevel processing efficiency and macrolevel measures of intelligence" (Ceci, 1990). The article discusses the alleged individual differences in the speed taken to encode stimuli, and notes that these appear to have some association with IQ. However, the name of this task (named in the references cited) is apparently unknown. Ceci then remarks that these differences are due to differences in how knowledge is represented in one's memory i.e.

> "the causal pathways that lead from microlevel performance to macrolevel performance are moderated by aspects of the ecology, including forces that differentiate one's knowledge base".

This objection may be possible for IT tasks in which the target stimuli are alphanumeric, but is unlikely for a task in which the discriminanda are two thin lines markedly different from one another. However, at least this proposition has some possibility of being testable, as one could use knowledge-dependent and knowledge-free visual IT paradigms, and use IT decision times as an index of the time taken to access the putative knowledge base. The weak reference to 'ecology ' is less impressive; one could equally argue that faster feature extraction and discrimination - all that IT really measures - bestows substantial evolutionary and ecological advantage, as the organism could use percepts to personal advantage, and would therefore be selected for.

The current thesis attempted to examine some of the more general, executive factors supposed to be involved in higher level problem solution. No strong evidence could be found for special acquisition, retention, transfer, or performance components during an IT task. Nor was the use of apparent motion cues attributable to a subject's conscious attempts to notice them, or the intelligence they brought to the task. It thus follows that the more general componential predictions derived from triarchic and metacognitive theories of intelligence contribute little to an understanding of the IT task, or the use by some individuals of apparent motion cues to guide their IT discriminations.

6.5. Overview: Strategies, intelligence, and society.

It is easy to see how strategic explanations have become attractive; researchers often work in an academic setting where intelligent young people with differing personalities talk their way through high-level 'real-world' problems. Articulate and ingenious arguments make the products of higher mental ability appear discernible by introspection, and even potentially teachable. This is rather more consoling than the possibility that IQ resists significant improvement despite time, money and enthusiastic intervention (Spitz, 1986). Strategies are now part of the psychological *zeitgeist* known as the "self-help" movement. It is of little surprise that, to the popular imagination, intelligence can be augmented by simple modifications akin to those that may improve one's psychic ability, managerial style, or sex life.

I would never object to public taste; they are enthusiastic and interested in psychology, and can always be better informed. By contrast, many academic and applied psychologists now realise that confidently stated theories or sustained rhetoric are all one needs to make a career, and being informed about an issue may ruin the flow of their argument. Thus, for example, Gardener's theory of multiple intelligences (Gardener, 1983) appears unfamiliar with Thurstone's previous (failed) attempts to divide intelligence into independent domains (Thurstone, 1938). Elsewhere, Robert Sternberg was led to write that one particular critic of the concept of intelligence "..dismisses a substantial body of physiological work in 28 words and one reference that is 12 years old. This dismissal seems hasty, at best". (Sternberg concludes that this particular idealogue "..is able to reach the conclusions he does only by ignoring massive amounts of prior literature" (Sternberg, 1988).) One is put in mind of Wilmarth (1898) who said that " .. such literature .. is occasionally deplorable when it deals with subjects of scientific interest, as it strongly impresses our minds with its subject while its inaccuracy makes it worse than valueless".

Strategic theories have been taken as truth largely because people want to believe them, not because of the compelling evidence laboriously accumulated in their favour. I sometimes fear that empirical criticism of rhetorical theories may not help, as the scientific method and experimentation has become unpopular in some areas of the social sciences. Will the methodological tool best suited for deciding which of our apparently material delusions, whims or insights is actually worth following be replaced by a discussion of 'perspectives'? I suspect not. Material facts have a way of returning despite wishes that they were otherwise, as demonstrated by the resurgence of Galtonian ideas. Whatever accounts for the use of apparent motion cues during IT tasks is not illuminated by *post-hoc* references to strategies. Refusing to empirically address difficult questions leaves us with Groucho Marx's immortal words: "I've made up my mind, don't confuse me with facts".

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Appendix 1. Raw data values for experiment 1.

(for details see chapter 2).

ID	SEX	AIT	BPP	VPEST	PTRIALS	LSTRETH	LTRIALS	PSTRAT	AH5A	AH5B	AH5C
2287	1	150	19	40	58	10	999	9	23	23	46
4539	0	100	19	10	39	10	999	9	17	21	38
0B34	2	70	17	999	999	10	38	9	99	99	99
0B55	0	85	19	42	69	62	97	9	16	14	30
0B16	2	200	17	105	177	40	144	8	15	22	37
0B45	2	55	19	999	999	999	38	9	99	99	99
0B54	0	85	17	59	71	10	63	9	13	19	32
0B46	1	40	17	41	97	22	118	3	17	19	36
0B43	1	55	16	40	129	10	38	0	22	27	49
0B39	0	85	18	82	135	59	65	9	19	11	30
0B17	1	200	17	42	73	38	135	1	20	26	46
0B41	0	85	13	40	133	10	38	9	21	23	44
0B50	0	85	18	38	67	38	58	2	24	24	48
0B44	2	40	20	10	38	10	91	0	18	19	37
0B29	0	85	17	85	87	68	999	9	13	17	30
0C23	0	100	18	60	149	59	219	8	13	18	31
4455	1	30	17	44	140	10	78	5	10	16	26
3300	0	125	18	18	100	10	38	1	17	24	41
0C11	0	70	18	40	70	41	89	3	13	14	27
0C12	1	55	17	41	76	10	38	5	23	26	49
0C17	1	55	19	10	38	10	38	3	19	26	45
0C19	0	70	18	39	80	208	67	0	16	14	30
0C22	0	85	18	10	39	64	189	0	13	25	38
0C26	0	100	13	30	93	10	43	3	10	14	24
0C42	1	85	16	60	240	96	65	3	9	18	27
0C43	0	70	18	19	77	10	88	1	14	23	37
0C54	0	85	20	10	60	10	66	0	17	19	36
0C53	1	55	18	80	141	10	38	8	14	23	37
0C55	1	85	18	10	999	10	999	9	14	17	31
0C42	1	85	16	60	240	96	65	9	9	18	27
0C28	2	125	18	999	999	10	999	9	99	99	99
0C32	2	70	17	999	999	65	150	9	13	16	29
2442	0	55	18	999	999	10	139	9	20	16	36
0C15	0	85	19	999	999	42	71	9	19	22	41
0D41	0	30	18	39	98	79	296	5	17	17	34
0D17	2	40	17	54	123	10	138	4	12	17	29
0D48	0	55	17	75	82	999	999	8	11	9	20
0D45	0	100	18	41	70	21	193	0	13	18	31
0D11	1	100	19	63	139	179	73	4	11	14	25
0D34	0	70	17	10	58	999	999	5	17	27	44
2211	0	70	17	10	64	999	999	0	15	26	41
0D16	2	70	19	56	125	999	999	0	23	21	44
0D37	0	70	17	39	80	999	999	0	13	14	27
0D43	0	70	17	10	43	38	60	5	12	20	32
0D55	2	70	18	72	999	999	999	4	20	25	45
0D23	0	70	18	10	58	16	146	2	14	16	30
0D46	0	70	18	50	105	21	191	0	14	18	32
0D49	0	100	17	43	74	45	93	5	22	21	43
0D56	0	85	18	999	999	999	999	9	19	22	41
0D50	2	40	17	22	64	999	999	7	21	29	50
0D57	0	85	18	40	103	999	999	8	17	23	40
0D33	1	100	19	26	107	999	999	5	18	19	37

Appendix 2. raw data for experiment 2.

for details, see chapter 3.

ID	SEX	DAY	UPIT	USTRAT	VIT	PTRIALS	PSTRAT	OSTRAT	AH5A	AH5B	AH5C
2519	0	1	73	8	80	171	8	9	17	21	38
0B30	0	1	63	8	89	999	8	9	15	16	31
0B51	0	1	42	0	48	133	0	0	11	13	24
0B40	0	1	125	8	56	179	8	9	14	25	39
2287	1	1	42	8	40	58	8	9	23	23	46
0B16	2	1	73	8	105	177	8	8	15	22	37
0B46	1	1	41	2	41	97	2	2	17	19	36
0B43	1	1	31	0	40	129	0	0	22	27	49
0B17	1	1	45	2	42	73	2	2	20	26	46
0B50	0	1	22	2	38	67	2	2	24	24	48
0C23	0	2	101	8	60	149	8	8	13	18	31
2623	1	2	94	8	80	216	8	8	18	25	43
4455	1	2	75	5	44	140	5	5	10	16	26
3954	0	2	54	8	36	227	8	8	11	6	17
3300	0	2	37	2	18	100	2	2	17	24	41
4822	0	2	71	2	67	102	6	8	14	22	36
0C11	0	2	42	2	40	70	2	2	13	14	27
0C12	1	2	62	5	41	76	5	5	23	26	49
0C14	0	2	41	6	40	78	6	6	19	25	44
0C19	0	2	46	0	39	80	0	0	16	14	30
0C20	0	2	85	8	40	59	8	8	8	19	27
0C26	0	2	46	2	30	93	2	2	10	14	24
0C42	1	2	48	2	60	240	2	2	9	18	27
0C43	0	2	43	2	19	77	2	2	14	23	37
0C51	1	2	60	0	44	190	8	8	15	21	36
0C53	1	2	87	2	80	141	8	8	14	23	37
0C27	1	2	63	2	41	999	2	2	23	22	45
0C31	0	2	42	4	39	79	4	4	17	20	37
0C13	0	2	11	0	39	176	0	0	9	19	28
0C56	0	2	56	0	40	73	0	0	15	19	34
0C42	1	2	48	8	60	240	8	9	9	18	27
0D13	0	1	81	0	40	214	0	0	18	19	37
0D41	0	1	52	5	39	98	5	5	17	17	34
0D17	2	1	42	4	54	123	4	4	12	17	29
0D48	0	1	42	8	75	82	8	8	11	9	20
0D45	0	1	34	0	41	70	0	0	13	18	31
0D11	1	1	41	4	63	139	4	4	11	14	25
0D29	0	1	66	8	62	71	8	8	13	20	33
0D12	0	1	47	0	41	78	0	0	20	19	39
0D28	0	1	47	6	80	104	0	8	15	22	37
0D16	2	1	41	2	56	125	0	8	23	21	44
0D37	0	1	13	0	39	80	0	0	13	14	27
0D14	0	1	47	4	79	73	6	8	12	20	32
0D55	2	1	44	4	72	999	4	4	20	25	45
0D22	1	1	46	8	36	160	8	8	14	18	32
0D44	1	1	76	2	62	144	2	2	17	21	38
0D46	0	1	60	0	50	105	0	0	14	18	32
0D49	0	1	50	2	43	74	5	8	22	21	43
0D38	0	1	62	8	43	109	8	9	21	27	48
0D57	0	1	62	8	40	103	8	8	17	23	40
0D33	1	1	64	5	26	107	5	5	18	19	37

Appendix 3: raw data values for experiment 3.

For details, see chapter 4.

ID	IT1	TRIALS1	IT2	TRIALS2	LSTRAT	PASAT1	DTPASAT
1	30.00	91.00	74.50	92.00	1	72.1	59.50
2	47.50	77.00	47.00	102.00	0	37.7	28.00
3	32.00	82.50	79.50	57.00	1	37.7	29.70
4	53.00	63.50	90.00	117.50	0	90.1	88.60
5	28.50	95.00	95.50	61.00	1	83.6	69.90
6	35.00	125.50	31.50	72.00	0	95.1	78.10
7	61.00	74.50	80.00	119.50	1	39.3	30.40
8	26.00	94.00	97.00	57.50	1	86.9	80.40
9	52.50	128.00	166.00	70.00	0	86.9	66.00
10	56.00	46.00	140.50	75.00	0	77.0	61.20
11	63.50	95.00	121.00	77.00	0	95.1	91.10
12	35.50	76.00	41.00	114.50	0	93.4	89.80
13	28.50	83.50	29.50	104.50	0	96.7	79.00
14	22.00	93.50	41.50	94.50	1	95.1	93.50
15	32.50	75.50	57.00	66.50	1	96.7	82.25
16	54.50	123.00	114.50	79.00	0	98.4	87.30
17	31.00	111.50	43.00	79.50	1	100.0	94.65
18	26.50	80.00	29.50	173.00	1	100.0	85.20
19	37.00	77.50	62.00	61.00	1	65.6	70.55
20	18.50	97.50	32.50	77.00	1	96.7	86.30
21	21.00	63.50	28.50	77.50	1	100.0	83.75
22	26.00	96.00	35.00	63.00	1	96.7	84.35
23	24.50	78.00	40.00	81.00	1	91.8	91.80
24	24.00	73.00	46.50	90.00	1	95.1	87.60
25	26.00	76.50	37.50	82.50	0	90.0	84.15
26	21.50	114.00	26.00	77.50	1	98.3	82.50
27	18.50	93.50	20.00	80.00	0	85.0	85.35
28	33.50	70.00	96.00	70.00	0	90.0	66.45
29	27.00	84.50	45.50	91.00	1	93.3	82.50

ID	VR	PR	TR	P	E	N	L
1	15.3	5.8	9.7	3	18	17	13
2	4.3	3.8	4.6	5	12	15	19
3	4.0	3.5	4.6	9	14	18	16
4	21.0	17.8	19.6	11	11	20	2
5	9.5	6.5	8.9	2	17	9	11
6	12.5	13.5	13.8	9	17	8	7
7	15.5	9.0	11.0	7	20	3	2
8	12.3	9.8	11.9	6	17	10	9
9	6.3	7.5	8.8	1	6	14	10
10	6.3	5.2	6.7	6	13	23	9
11	13.5	13.3	13.7	2	5	9	14
12	17.8	25.0	22.6	1	11	9	10
13	18.5	24.8	23.2	0	20	17	8
14	23.5	27.3	26.1	1	16	17	4
15	23.5	22.3	23.6	16	20	1	3
16	15.0	13.5	10.9	3	16	8	5
17	11.3	13.8	10.0	5	17	12	1
18	16.5	21.0	19.0	1	18	9	6
19	17.8	12.5	16.2	1	11	1	15
20	19.0	26.5	24.9	1	16	4	7
21	24.8	24.2	24.0	5	14	21	2
22	20.8	18.5	19.4	3	17	9	0
23	21.0	18.7	19.9	4	12	13	8
24	14.0	11.8	9.9	4	6	10	5
25	4.8	7.7	5.5	10	16	13	4
26	15.5	17.0	12.8	2	19	6	2
27	14.5	14.7	15.4	3	19	14	8
28	7.8	14.7	11.2	3	14	13	6
29	29.0	25.2	27.3	7	14	21	0

Appendix 4: Raw data values for experiment 4.

For details see chapter 5.

ID	SEX	SPM	MHB	P	E	N	L	BASERT	CSD	CSD-RT
1	0	41	17	6	12	10	9	999.9	7	75.1
2	0	43	22	8	11	19	13	999.9	5	54.0
3	0	36	19	7	19	22	7	26.2	5	37.5
4	0	36	26	1	8	15	11	65.2	12	51.7
5	0	27	10	7	16	18	16	55.1	12	65.9
6	0	37	17	0	9	12	16	42.7	4	51.2
7	0	46	19	1	17	2	9	34.1	7	57.5
8	0	45	17	6	15	18	6	67.0	9	66.9
9	1	99	27	7	6	18	4	15.5	9	59.5
10	1	50	19	5	11	5	12	41.2	3	55.7
11	1	39	17	5	15	21	4	35.1	3	55.7
12	1	53	25	3	12	8	5	34.5	10	24.5
13	1	42	23	10	19	16	8	13.8	6	27.1
14	0	33	25	4	12	22	2	36.4	5	77.8
15	1	40	23	5	9	10	9	94.0	8	33.2
16	1	42	19	8	16	10	6	15.2	6	27.3
17	1	47	16	6	17	9	7	20.2	10	30.2
18	1	41	21	6	13	11	12	21.2	7	31.6
19	1	40	24	2	14	15	4	37.0	5	48.5
20	1	41	25	6	19	5	10	10.7	6	34.7
21	1	45	22	8	15	8	5	16.2	6	31.5
22	1	44	26	11	14	8	11	33.8	5	39.6
23	1	45	22	10	9	7	2	28.6	6	45.2
24	0	42	25	3	5	18	13	20.4	11	36.2
25	0	42	21	2	15	13	18	19.1	8	25.5
26	0	45	24	4	17	16	12	28.7	5	50.0
27	0	36	22	5	18	19	4	28.9	5	52.0
28	0	50	28	2	6	18	3	30.4	6	23.4
29	1	48	21	11	6	15	6	26.2	14	41.2
30	0	33	14	3	15	18	17	63.9	4	76.7
31	1	49	28	3	16	6	14	13.8	5	23.2
32	1	48	23	0	11	7	9	9.0	7	16.2
33	1	37	16	7	14	9	8	20.6	11	27.5
34	0	47	28	5	14	18	7	44.5	4	46.8
35	1	39	20	6	14	11	14	13.6	8	21.6
36	1	37	25	0	7	12	12	25.2	5	38.2
37	1	16	15	12	13	11	15	46.9	7	109.6
38	1	45	24	5	17	12	1	27.9	5	39.2
39	1	42	25	7	19	6	7	88.2	16	81.9
40	1	47	26	5	20	15	6	20.2	6	27.6
41	0	38	19	6	13	7	13	21.5	8	35.2
42	0	17	20	10	13	7	13	29.3	12	36.5
43	0	16	14	3	14	8	9	22.6	5	20.2
44	0	29	20	6	20	17	2	52.2	9	37.7
45	0	23	19	3	20	15	12	13.1	6	18.3
46	0	39	25	3	9	19	7	19.0	8	23.9
47	0	13	15	8	13	18	16	19.0	5	24.6

ID	IT	LIT-RT	LITSLOPE	LINCEPT	LSTRAT	SIT	SIT-RT	SITSLOPE	SINCEPT	SSTRAT
1	31	57.1	-.38	85.1	1	32	39.5	-.09	46.8	0
2	40	43.0	-.22	66.0	1	26	57.8	-.20	70.8	1
3	34	46.5	-.22	62.7	1	25	33.6	-.10	41.5	1
4	56	160.2	-.41	204.6	0	38	89.7	.29	63.1	0
5	147	112.7	-.84	255.8	0	59	59.3	-.06	53.9	1
6	29	255.8	2.81	-20.9	1	38	92.7	-.16	107.3	1
7	31	53.8	-.23	70.7	1	36	54.5	.47	50.2	1
8	29	106.2	.69	45.6	1	38	77.2	-.23	97.9	1
9	23	75.5	.78	19.7	1	22	74.1	.00	73.7	1
10	19	39.0	-.21	52.2	1	23	48.1	-.13	58.1	1
11	16	88.7	.22	47.3	1	99	9999.9	99.99	9999.9	9
12	23	50.9	.04	47.5	1	18	64.1	.37	36.3	1
13	71	75.7	-.82	162.7	1	40	53.0	.12	40.5	1
14	29	66.9	-.03	69.2	0	29	72.9	.07	66.9	0
15	29	34.6	-.21	53.3	0	24	32.3	-.10	40.5	1
16	26	25.9	-.09	33.5	1	27	35.0	-.07	41.4	1
17	41	27.7	-.22	46.5	1	29	32.5	-.20	49.8	1
18	28	51.0	-.18	63.0	1	28	41.9	-.15	52.3	1
19	31	50.1	-.07	55.3	0	30	48.9	.54	12.4	0
20	18	39.8	-.21	55.5	1	29	18.3	-.12	29.2	1
21	28	55.6	.48	24.5	0	45	37.8	-.10	48.0	0
22	35	75.3	-.48	111.6	0	99	9999.9	99.99	9999.9	9
23	27	48.2	-.10	56.7	0	26	40.9	-.17	52.0	0
24	31	44.4	-.36	76.4	0	25	48.0	-.08	53.9	0
25	53	33.3	.01	30.0	4	21	23.2	-.13	36.5	1
26	22	62.7	-.36	92.1	0	31	50.2	-.25	68.2	1
27	15	67.9	-.32	87.7	1	20	46.6	.05	43.0	1
28	31	46.4	-.32	72.0	0	31	29.2	-.03	32.0	1
29	91	53.6	.22	27.2	0	68	50.5	-.23	78.1	1
30	57	100.7	-.32	113.1	0	48	112.7	-.49	157.2	0
31	25	24.1	-.13	34.0	1	25	25.0	-.17	37.9	1
32	33	12.7	-.12	22.3	1	27	15.5	-.10	24.0	1
33	31	36.9	-.22	52.1	0	39	33.1	-.05	37.0	0
34	24	41.6	-.07	47.5	1	29	24.6	.00	24.2	1
35	29	18.3	-.18	32.9	1	24	25.7	-.25	47.1	1
36	24	59.4	-.05	63.8	1	16	43.1	-.12	51.4	1
37	71	102.5	.10	91.8	1	41	57.6	-.21	76.4	1
38	30	42.8	-.33	67.5	1	16	69.8	-.50	102.8	1
39	62	104.3	.07	97.0	0	75	71.0	-.10	82.8	0
40	34	35.8	-.21	53.1	0	38	31.6	-.03	34.0	1
41	27	27.7	-.24	48.9	1	25	46.5	-.05	50.0	1
42	42	100.5	.05	96.5	1	46	46.4	-.11	55.9	1
43	33	70.6	.32	37.3	1	27	35.4	-.05	39.2	1
44	41	54.6	-.49	93.2	0	34	52.8	-.21	69.9	1
45	51	38.9	-.41	77.1	1	71	17.7	.05	12.4	0
46	38	53.6	-.37	94.2	0	36	37.1	-.18	50.6	0
47	104	11.4	-.06	18.5	0	38	7.1	-.03	9.7	0

Appendices 5 to 7. Published papers from this thesis.

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INTELLIGENCE AND INSPECTION TIME: DO HIGH-IQ SUBJECTS USE COGNITIVE STRATEGIES?

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Summary—It has been suggested that 'inspection time' (IT) can be aided by specific strategies, and that high-IQ *S*s would therefore be advantaged on this task. However consideration of previously published findings from university students suggest that such strategies cannot currently be taught with any degree of success, and that strategy use may disrupt rather than explain the IT–IQ relationship. Correlations between IT and IQ for high-IQ *S*s not using strategies are consistent with previously observed data, perhaps from −0.3 to −0.6. Despite considerable variation in the IT technique used, similar results are being obtained by different researchers. It is not possible to prove that no strategies at all have been used by *S*s, but re-interpretation of current evidence suggests that this source of bias is overstressed. By applying Baron's formal criteria for identifying strategies, it becomes possible to test whether strategies have been used or not. Failing a clear statement of what counts as evidence of strategy use, particular strategies must be examined for their impact on IT when *S*s have been fully trained in their use.

INTRODUCTION

Miller (1962) says that "... (generally) ... no activity of mind is ever conscious". This suggests the mandatory nature of the preconscious processing by which cognitive products enter conscious awareness [cf. Fodor (1983) for a modern version of this view]. We do not think about our perceptual treatment of events around us. It simply happens. This follows for more complex operations too, as Dixon (1982) shows. We are unconscious of the automatic information-processing tasks we perform, and possibly this overlaps into broader psychological functions, enabling the rapid and accurate transmission of external sensation to the more mysterious operations of our minds. Furneaux (1960) would have been sympathetic to these views. He suggested that possibly the 'operating parameters' of the input systems, especially speed and accuracy, could shape the underlying differences in mental abilities. Brand and Deary (1982) have similarly hypothesized that the rate with which the individual samples the environment is at the root of general intellectual capacity, and that this is free of higher influences.

'Inspection time' (IT) is a construct concerned with the accuracy of a *S* in very simple discriminations. It gives an estimate of the speed at which an individual processes and responds to an initial stimulus prior to its registration in short-term memory (Brand, 1984); measurement procedures are described elsewhere in this issue by Vickers and Smith (1986, pp. 609–623). A number of doubts have been raised about IT. Most recently it has been suggested that cognitive strategies may confound this measure of perceptual speed. From Nettelbeck and Lally (1976) to Smith and Stanley (1983), it has been evident that *S*s may be able to use various strategies, thereby reducing the effectiveness of this method as a valid, non-cognitive index of ability.

Cognitive strategies are habitual ways of selectively attending to information and organizing it into meaningful categories (Mischel, 1973). In an ambiguous, indeterminate and complex world, various heuristics aid us in the solution of problems related to the treatment of information. For example, Baron (1978) suggests that human intelligence is subserved by three central strategies: stimulus analysis, relatedness search and checking. These are overseen by 'metacognition', i.e. strategies for using strategies. From such structures we can generate techniques such as rehearsal, mnemonics and successive approximation. According to this approach, the capacity and proficiency of the individual will affect how strategies are executed. Baron emphasizes that these strategies are modifiable by educational manipulation, so making strategy research practical. Secondly, he argues, strategies are the most observable form of intelligence. Indeed, he says that there is "no interesting difference between age or ability group that must be ascribed to differences in capacities". He finally suggests that as capacities influence the manifestation of intelligence through their influence upon the acquisition and use of general strategies, if we can discover the strategy types, we can isolate the basic capacities of man.

Brand and Deary (1982) have noted that the linear relation between IT and IQ may break down amongst high-IQ *S*s. This could be due to cognitive processes like those proposed by Baron (1978). Thus, the acquisition of a simple strategy could limit the extent to which IT may be said to reflect some simple information-processing operation, due to early perceptual processing being augmented by some elementary cognitive operations. If this is so, such techniques could be teachable given the appropriate circumstances.

PROBABILISTIC STRATEGIES

Fitzmaurice and Nolan (1983) have suggested that probabilistic strategies can account for the observed correlations between IT and IQ in more-able *S*s. This is supposedly because the apparent simplicity of the decision required provides a predictable sequence within the experimental task. Referring to Anderson (1977), who showed that the IT–IQ relationship declined (though remained significant) as the number of stimulus lines in the experimental task increased from 2 to 4, Fitzmaurice and Nolan have suggested that the more complicated task prevents the possibility of applying an inferential strategy. They argue that high-IQ *S*s use 'intelligent guesswork' to isolate systematic runs of repetitions and alternations in experimental stimuli. This may lead to greater than chance scores at exposure durations at which it is impossible to discriminate, and would not work if the task was made more difficult. Thus presenting the experimental stimuli in a truly unpredictable sequence or increasing the complexity of stimuli should impede the use of a simple strategy.

To support this, they divided a sample of *S*s into two groups, greater and less than IQ 110. They then conducted two experiments, one concerned with sequential factors, the other with the increasing complexity of the stimulus array. In Experiment 1 they presented stimuli within a 'Fellows sequence' (Fellows, 1967), the intention being to ensure that no strategy produced other than chance performance. The only significant relation they found between IT–IQ was in the low-IQ sample presented with the control condition of randomized stimuli ($r = -0.62$, $P < 0.05$). The IT–IQ correlation in the Fellows sequence condition was only 0.06. A strong IQ × condition interaction was observed, supporting their hypothesis of differential strategy use among the more able. No significant correlations were found for *S*s in Experiment 2, which examined the effect of increased stimulus complexity on IT. It therefore appeared that IT–IQ correlations could be shown to be artifactual, to the extent that the task is penetrable by simple strategies amongst the more able.

Several assumptions are implicit in their Experiment 1, namely that IT and IQ are not correlated in any fundamental sense, and that *S*s can penetrate a random, but not a Fellows sequence. From this one predicts that a non-significant result should be obtained where the stimuli sequence is unpenetrable. However, by starting from the converse position, that IT and IQ are related, a different prediction is possible. Assume that the Fellows sequence is penetrable by the strategy of 'no more than three on any one side' (Brand, personal communication, June 1985). Given the experimental *S*s' willingness to apply the 'gamblers fallacy' to randomly related items, it is plausible to see other ways in which the *S* can affect experimentation, that other subject strategies could emerge also. If one assumes some IT–IQ relationship, a non-significant result would be expected if the Fellows sequence was penetrable but the random sequence was not.

It is arguable that a random sequence is not penetrable in the way Fitzmaurice and Nolan (1983) proposed. If one uses cognitive strategies, one needs feedback from the situation so that *S*s can approximate and 'hypothesis test' their way of doing the task. In Edinburgh and Adelaide the IT research has involved using a 'staircase stimulus sequence' that targets the task to the *S*s' optimal, asymptotic level of performance. It is therefore a reasonable assumption that any feedback from the task is minimal.

The rationale behind Fitzmaurice and Nolan's Experiment 2 was that as the number of lines in the IT display increases, the IT–IQ relationship reduces. This is correct, but fails to consider the full results obtained by Anderson (1977), who found that correlations for two-, three- and four-line stimuli with IQ were all significant, at $r = -0.88$, -0.78 and -0.66, respectively. A comparison of the four highest- and lowest-IQ Ss showed no significant differences in IT for the two-line task and those involving greater stimulus complexity. This finding established that though there is a very significant negative relation between IT and IQ for 1, 1.5 and 2 'bits' of information, the prediction that high-IQ Ss will perform differentially better than low-IQ Ss as the information load increases was not supported. When stimuli are being presented at durations below that of saccadic eye movements, it is obviously important to have the stimuli in foveal vision. Anderson (1977) gave his Ss rather more practice on the task, enabling the Ss to improve their scanning of the stimulus material, unlike Fitzmaurice and Nolan (1983). This may account for the discrepancy between the results obtained for the different experimenters.

APPARENT-MOTION STRATEGIES

Rather more challenging to IT is the problem of apparent-motion effects, that occur in all backward-masking methodologies. Nettelbeck (1982) has said that in virtually all IT studies "some subjects have been able to make use of information other than the briefly exposed stimulus figures, such as subtle post-masking cues associated with apparent movement". This tendency may plausibly explain the breakdown between IT and IQ within groups of higher ability. Mackenzie and Bingham (1985) measured IT among a sample of students from the University of Tasmania (WAIS mean IQ = 116.2, SD = 8.4) on a fully computerized task. They found that, from the self-reports given, some of the Ss were naturally using a strategy based on apparent motion. Mackenzie and Bingham then divided the sample into users and non-users, and tried to teach the non-users to notice movement cues. Ss were told to 'choose the line that moved the most, then point to the other line'. It was found that the natural strategy users had significantly lower mean IT than non-users, although the two subgroups were not significantly different from one another on the WAIS or any of its subtests. [Brebner and Cooper (1986, this issue, pp. 709–714) have suggested that differences of this kind may be due to individual differences in personality affecting performance.]

For strategy users, no significant correlations between their IT and IQ were found, while among the non-users IT was highly correlated with performance IQ and especially with scores on the Block Design and Object Assembly WAIS subtests ($r = -0.71$, -0.89 and -0.78, respectively). Importantly, it was found that this strategy could not be taught to the Ss; they could either use it or not, independent of their measured IQ. The IT–IQ correlation obtained was not the result of differential strategy use by high- or low-IQ Ss, although this use of strategy produced lower mean IT than did non-use. However, requiring non-users to apply the strategy resulted in a slower IT.

From the results obtained, it is possible that presenting the experimental stimuli on a computer monitor led to a strong relationship (for the non-users) between IT and visuo-spatial WAIS subtests. This could have been due to the related issues of foveal vision and stimulus scanning being affected by rapid presentations if a fixation point is not fully established.

From Mackenzie and Bingham's (1985) results we can conclude that there are qualitative differences within a normal sample of Ss in the extent to which an effective strategy for performing an IT task can be applied. However, this study has shown that, even amongst a high-IQ sample, IT is significantly related to IQ for those unable to use apparent-motion cues. Both this experiment and those by Fitzmaurice and Nolan (1983) show how the observation of Ss under conditions in which it is assumed that they are using strategies can aid our understanding of IT and the operation of strategic factors generally.

Currently strategies cannot be taught with any degree of success, but individual Ss may be able to use them. It is therefore best to assume that Ss will generate strategies, given any regular order in a testing sequence. If one observes Ss with this assumption in mind, it may be possible to establish the circumstances in which some strategies are used, and their effects on the IT–IQ relationship.

RECENT IT RESEARCH FROM SCOTLAND

Research from Aberdeen University provides a novel perspective on the apparent-motion effect. Critical stimulus duration (CSD) is the duration of an unmasked stimulus at which a *S* can achieve a predetermined criterion of success. Sharp (1984) established that the degree of correlation between CSD and Raven's Matrices (RPM) scores to be approximately the same as with IT and RPM, irrespective of whether a backward-masking procedure was followed or not [$r = -0.49$ ($P = 0.02$) and $r = -0.54$ ($P = 0.01$), respectively]. This may suggest that IT and CSD measure basically the same process, and the presence or the absence of forward and backward masks may make little difference in the outcomes obtained. If this were shown to be so, whether apparent-motion strategies were used or not could be seen as irrelevant.

Sharp (1982) previously suggested that IT may reflect the time for which a stimulus must be available before a sufficiently intense icon can build up for subsequent decision-making processes to follow. If one looks at this in terms of a general 'perceptual accumulation' efficiency model, IT performance in other sensory modalities should be very similar to that obtained in the visual modality. This outcome would confirm the central nature of discrimination, consistent with Hendrickson and Hendrickson's (1982) average evoked potential (AEP) 'string length measure' of EEG, also found to correlate strongly with IQ. It would also further emphasize that speed and efficiency are rather more similar concepts than has previously been recognized.

Not all strategies are spatial or inferential; they may include the linguistic coding of percepts. However, a study from Edinburgh challenges the view that IT effects are due to verbal cognitive strategies (Bain, 1983). Deaf children could be considered a highly culturally retarded sample of *S*s. Thus this handicap could lead to poor performance on IT and, because of their early difficulties in interaction with their environment, poor performance on IQ tests also. Strategy theorists may argue that such a sample would lack the experience needed to generate strategies that could penetrate such a basic cognitive task. Using a computer-controlled two-line LED display discrimination task to obtain IT, and relating this to RPM, yielded correlations of -0.30 between IT and IQ for the full range of abilities within this sample. Further, only among the children with below-average ability did mental tests correlate significantly with themselves, and here IT correlated at -0.60 with the tests for the sample. This result supports the suggestion that the relationship between IT and IQ remains strong within most of the IQ continuum, but reduces at higher levels, where other factors may enter into the process. This suggests that the finding is essentially the same as that widely reported for non-handicapped population, and may propose that IT taps some quite fundamental process, largely independent of environmental experience and outside strategic intervention. It is unlikely that verbal strategies are applicable for the younger deaf and, if Sharp's work is valid, apparent-motion effects may be less confounding than some have suggested. Strategies may be largely useless in the penetration of fundamental cognitive operations. If the strategy cannot be taught to more-able *S*s, this would suggest that it would be difficult to acquire by those of lower abilities.

DISCUSSION

The foregoing does not suggest that strategic factors are unimportant, but rather that research to date has not specified cognitive effects on IT. Despite being interpreted as posing a serious challenge to the IT phenomena, the results so far obtained do actually tend to buttress earlier results.

However, the possibility of strategic factors being used must be considered. Besides the obvious problem that strategies may still partly confound IT research, they also raise interesting issues concerned with the extent to which conscious and preconscious processes relate to one another in areas such as attention and time perception. With this in mind, Baron's criteria for teaching general strategies should be applied by those doing IT research. This means *S*s should be taught strategies explicable in natural language. Such strategies should be able to influence the acquisition of other, less-general strategies. One question to be tested would be to see how the selection of different strategies varied for those with different abilities. This in turn could be examined by having *S*s perform on apparently similar tasks in which a strategy is more helpful for one version of the task than for another; for example on an LED IT task involving a two-line discrimination compared to a tachistoscopically-presented one. If the strategy has been acquired, it could be applied to both conditions. One could also have Ss learn the apparent-motion strategy in relation to a number of tasks, then compare performance on these to that on other tasks and examine the possibility of a general positive-transfer effect.

The experimenter inevitably has the problem of finding out if a strategy has been used by the S. If a strategy is procedural, for example, it may be difficult for the S to express it in self-report. Wilson (1984) provided a technique that may overcome this difficulty. She suggested that the performance of those Ss using strategies would have a restricted within-individual variance when compared to those not using strategies. Such Ss' performance would also be more accurate, showing consistency as a consequence of their strategy usage. A statistical analysis of results could therefore guide the hypotheses generated by a S's introspections.

The alternative to this, that strategies are simply assumed to operate, would, of course, be untenable for any systematic approach to the structure of individual differences. If strategies cannot be shown to have any effect on IT performance, and their application cannot be falsified, then they are as much part of the metaphysical and psychological *Zeitgeist* as psychoanalysis or sociobiology; and of the same limited usefulness in the understanding of human cognition.

IT is just one of the information-processing 'non-cognitive' measures of IQ currently under study within the field of intelligence. Among others are Hendrickson and Hendrickson's previously mentioned AEP work [replicated by Caryl and Fraser (1985)] and Jensen's various reaction time (RT) studies (e.g. Cohn, Carlson and Jensen, 1985). In the case of the RT research, it is only through multiple correlations that significant results are being obtained. Otherwise, as Hunt (1980) has noted, individual measures correlate with intelligence at only -0.30. By comparison, AEP and IT studies are getting relationships that accommodate at least 25% of the variance on IQ tests. This suggests that both of these approaches track some structural underpinning of human ability. One cannot deny that higher processes enter into functional adaptation, but one should be cautious about the extent to which they operate. The possibility that apparently simple measures of processing may be converging to provide a theory of human intelligence illustrates Poincaré (1902): he said that as our knowledge gains variety and complexity, our theoretical understanding ensures a convergence into unity and simplicity.

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PASAT: observed correlations with IQ

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Summary—Relations between psychometric measures of intelligence and the clinical Paced Auditory Serial-Addition Task (PASAT) were examined in a non-clinical group of young adults. PASAT correlated with the six separate psychometric scales, and especially with an overall estimate of non verbal intelligence ($r = 0.71$, $P < 0.001$). One-minute samples of PASAT performance were also strongly correlated with intelligence (median $r = 0.62$, $P < 0.01$). The results suggest that PASAT is correlated with general intelligence and numerical ability, contrary to previous claims.

PASAT is a test used to measure the reduction of patients' information-processing capacity following minor to moderately severe closed head-injury (Gronwall, 1977). During the test subjects are asked to listen to a recorded series of single digits and add each number to the one presented previously. Digits are presented at a constant pace, once every 2 or 4 sec. Little demand is placed upon memory: subjects need only remember one number, add it to the next and store this currently heard digit. Once the subject knows what to do, task difficulty consists primarily in the pacing. Practice on PASAT improves performance only slightly, compared to the major improvements that follow a patient's recovery from concussion (Gronwall, 1977).

When they factor-analysed a combination of clinical measures concerned with memory impairment, Gronwall and Wrightson (1981) found that PASAT loaded chiefly on a factor of attention, concentration and information-processing capacity; and that this factor had no substantial correlation with a factor of verbal competence. This was taken to support their previous claim that PASAT was "not significantly correlated with either general intelligence or arithmetic ability".

PASAT, however, involves relatively elementary information-processing based on the speed of intake; tasks of this type have sometimes appeared to have substantial correlations with general intelligence (e.g. Nettelbeck, 1987). So is PASAT really intellect-free?

28 subjects were collected from schools and Youth Training Schemes (mean age 16 yr, 7 months (SD 9.7 months)). The spread of ability on the Standard Progressive Matrices (SPM: Raven, 1977) approximated to normality (mean IQ 101.4, SD 15.4, population range 75–120).

Testing was conducted in two blocks, one concerned with IQ tests, one with PASAT. Measures obtained were the percentage accuracy on the full PASAT task, and for each 1 min epoch within it. Subject completed the Alice Heim 2 (AH2: Heim, Watts and Simmonds, 1974), the Cattell Culture–Fair (CCF: Cattell, 1973) and Mill–Hill Vocabulary (MHV: in Raven, 1977) tests. 5 subjects were not present at the main testing session, and did not complete the AH2. Additional verbal, performance and total scores were derived by adding appropriate tests together (VC, PC and TC respectively).

PASAT was presented as described above (Gronwall, 1977). Subjects were given unpaced practice on PASAT until they were 100% accurate. They were then given practice on a paced practice version of the task, presented in the form of a tape-loop. This familiarised them with a more quickly-paced task. Following this paced practice, subjects were given the PASAT task proper, in which subjects heard 61 digits, one every 4 sec. These were presented by cassette also. During the inter-stimulus interval subjects made their response verbally. The experimenter recorded this on a scoring key.

Mean percent accuracy for PASAT was 87.1 (SD 16.1); in each 1-min epoch the means and standard deviations were, respectively, 92.4 (16.1), 89.1 (14.2), 84.8 (20.1) and 85.5 (18.9). These results suggest a ceiling effect. Irrespective of epoch or full task, mean percentage accuracy and standard deviation remained about the same, inplying high internal consistency for PASAT. This is supported by correlations between the four subtest epochs and full PASAT [respectively $r = 0.92$, 0.95, 0.93 and 0.93 (all $P < 0.001$)]. PASAT's split-half reliability was 0.96 ($P < 0.001$).

Table 1. Correlation of PASAT with psychometric measures

	PASAT	
Alice Heim 2 Total	0.65	**
Alice Heim 2 Verbal Scale	0.52	*
Alice Heim 2 Numeric Scale	0.67	**
Alice Heim 2 Perceptual Scale	0.69	**
Standard Progressive matrices	0.63	**
Mill–Hill Verbal (test B)	0.41	*
Cattell Culture–Fair	0.73	**
Verbal Composite Score	0.51	*
Perceptual Composite Score	0.71	**
Total Composite Score	0.68	**

*$P < 0.05$. **$P < 0.001$.

Table 1 shows that PASAT correlates substantially with most measures of intelligence for the sample: for example, PASAT correlated with TC at 0.68 ($P < 0.001$). Although PC correlated somewhat higher with PASAT than did VC, the differences between these correlations did not approach statistical significance.

Correlating each 1 min epoch with the IQ measures indicated that the PASAT-IQ correlation was not simply a product of fatigue on the full 4-min task. The median correlations of the psychometric measures with the four PASAT epochs were: for VC 0.48 ($P < 0.05$); PC 0.64 ($P < 0.01$); AHN 0.63 ($P < 0.01$); TC 0.62 ($P < 0.01$). Hence both performance and numerical measures correlated well with performance on 1-min PASAT epochs. PASAT is not, as Gronwall and Wrightson (1981) claimed, uncorrelated with general intelligence or arithmetic ability, at least in normal subjects.

One objection to this result may be the ceiling effect observed. This could be reduced by subjects having to do PASAT at the rate of one stimulus every 2 sec. By virtue of the reduced spread of performance, ceiling effects tend to lower correlations. With a better distribution of PASAT scores, would the correlation increase?

Hunt (1983) said that "the cognitive science view is that intelligence is an abstraction and does not have a cause" (pp. 146). The relationships shown here suggest that such a view may be unduly theoretical; there is nothing abstract about the strength of the phenomena observed. His claim that, because cognitive tasks tend to correlate with IQ tests at only 0.20 or 0.30, the information-processing approach to IQ is as useful as "the search for the Holy Grail" (Hunt, 1980) also looks short-sighted: many simple experimental tasks seem to be emerging, showing rather stronger relationships with IQ measures.

PASAT has been used to study concussion for 15 years, and was not considered to relate to non-clinical variation in mental abilities. Possibly other 'non-cognitive' measures in daily usage by experimental and clinical psychologists are also chiefly measures of the testees' general fluid intelligence (*gf*).

The present study enables a traditional understanding of why PASAT correlates at relatively low levels with measures of crystallised intelligence (*gc*) in patients who have suffered recent head-injury: in these patients *gc* and *gf* are differentially affected by the injury.

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NOTES AND SHORTER COMMUNICATIONS

Links between personality, ability and attitudes in a low-IQ sample

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Summary—Despite considerable reference to those on the Youth Training Scheme (YTS), little is known of their psychometric test performance. YTS trainees were tested on measures of verbal and non-verbal intelligence, personality, attitudes and hostility. The range of ability in the sample varied considerably: one third (30) of the subjects had IQs less than 90, 10 of these having IQs below 75. The remainder had IQs ranging from 90 to 117 (median IQ = 98). YTS trainees were higher in neuroticism (N), psychoticism (P), lie-telling (L) and social conservatism (C) than norms for a sample of similar age and sex. Correlations between tests suggest that IQ has a significant negative correlation with C ($r = -0.39$, $P < 0.001$), outwardly expressed hostility and L, whilst L is strongly linked to C ($r = 0.53$, $P < 0.001$) and C subscales. P was strongly correlated with measures of outwardly-directed hostility (mean $r = 0.39$, $P < 0.001$), while N was correlated at a similar magnitude to measures of inwardly expressed hostility. Sex differences reflected earlier findings: females were significantly more neurotic than males, males more overtly hostile (and had higher P scores) than females. The SPM/C correlation is discussed in relation to the view that the apparent rise in global IQ is a product of reduced social conservatism.

INTRODUCTION

The Youth Training Scheme (YTS) provides training for those school leavers who leave school with few (if any) qualifications, and remain unemployed for the 6 months following. Being provided with various basic occupational skills, the YTS trainee is able to claim modest experience in a job domain and so hopefully enter the world of work proper. Trainees are also given what is called 'Training for Life', which covers the broader social issues of racism, sexism and politics. In a time where youth unemployment is widespread, and where British political attitudes are polarising along somewhat geographic lines, one would expect YTS trainees to have liberal and radical attitudes. This is not empirically known. Nor are even more basic psychometric facts: what are typical levels of IQ or personality for such a sample?

Small but significant links between attitudes and personality have been established; using the Wilson–Patterson Attitude Inventory (WPAI) to measure social conservatism (C), Nias (1973) found a correlation of -0.29 ($P < 0.05$) between psychoticism (P) and C, of -0.26 ($P < 0.05$) between extraversion (E) and C, and of 0.33 ($P < 0.05$) between 'lie telling' (faking good; L) and C. Modest (but significant) correlations between P, E and L were also observed with the WPAI realism–idealism (R) measure (rs respectively 0.36, 0.23 and -0.15, all $P < 0.05$). These correlations were on a sample of 119 Ss, derived from the general population. This pattern of correlations held, but at slightly higher levels, in a sample of 95 students, whom one would expect to be higher in ability and more socially liberal, than the general population.

IQ is another variable that correlates slightly with C; Eysenck and Coulter (1972) reported significant correlations of 0.23 between the Standard Progressive Matrices (SPM) and Radicalism, of -0.25 between the SPM and the Californian Ethnocentrism Scale, and of -0.28 between the SPM and the Californian Fascism Scale. This was found amongst a sample of 86 conscripted British soldiers whose voting intentions were closely similar to those of the British working class as a whole. Less conclusive was an unpublished study by Bagley and Verma (1973), who showed no significant link between Cattell's HSPQ 'B' scale and C among 492 adolescents ($r = 0.10$, NS). The B scale assesses self-rated concrete or abstract thought. If one is to assess links between ability and attitudes, it may be better to use a specific ability test, rather than the less precise scales found in the HSPQ or 16PF.

The link between C and IQ has been considered by Brand (1987) as a possible explanation of the global increase in culture-fair IQ (Flynn, 1987; Lynn, Hampson and Mullineux, 1987). His theory proposes that Ss showing higher degrees of C are less inclined to intelligently guess, or selectively respond, to the items in timed IQ tests such as the SPM. Differential responding amongst those high in C would reduce the number of items correctly responded to, and so reduce the final 'IQ' score of high-C Ss. Brand thus suggests that the decrease in social conservatism may account for the apparent increase in IQ.

With this in mind, YTS trainees were tested on five standard psychometric instruments, the intention being to see:

(a) What the psychometric baselines and ranges on standard psychological tests for this sample would be, and
(b) To what extent these correlated with one another, with particular reference to any correlation between the SPM and C.

METHOD

Subjects

Ninety-four trainees were tested (mean age 16.7 yr, SD 9.7 months). Typically they had been unemployed for 6 months following their leaving school and were graded Mode B—in need of basic training before employment. At the scheme attended they were trained in joinery, knitware, painting and decorating, clerical skills, computing or catering.

Psychometric tests

Differential patterns of testing were given to the *S*s, contingent upon the testing period available to the experimenter. The following tests were administered.

The SPM

The SPM (Raven, 1962) is a culture-fair IQ test particularly loaded on a *g* factor. *S*s select one of a number of picture choices (SPM) that would complete a pattern matrix. The test was administered with a 30 min time limit.

The Mill–Hill B (MHB)

The MHB is the second part of the Mill–Hill Verbal Ability test. *S*s are requested to underline the correct synonym out of six possible choices presented for a particular word. This was given with a 15 min time limit (though all *S*s had completed it in 10 min).

The Eysenck Personality Questionnaire (EPQ)

The EPQ (Eysenck and Eysenck, 1975) assesses behaviour on four independent dimensions; *P*, *E*, *N* and *L*.

The Wilson–Patterson Attitude Inventory (WPAI)

The WPAI (Wilson, 1975) is a refinement of the original '*C*' scale developed by Wilson and Patterson (1968). It takes into account other aspects of general behavioural and social conservatism, and has two main dimensions, *C* and *R*. *C* is comprised of four subscales; militarism–punitiveness (MP), anti-hedonism (AH), ethnocentrism (EC) and religion–puritanism (RP). High scores on these subscales contribute to the high *C* score.

The Hostility and Direction of Hostility Questionnaire (HDHQ)

Developed by Caine, Foulds and Hope (1967), the HDHQ takes the view that basic hostility can be expressed in differing ways. The HDHQ samples a range of possible expressions of aggression, hostility and punitiveness. The first three subscales—acting in a hostile way (AHO), criticising others (CO) and projected delusional hostility (PH)—consider extra-punitive hostility. The last two, self-criticism (SC) and guilt (GUILT), measure intra-punitiveness. In practice all the measures are added together to generate a total hostility score, and the intra and extra-punitive measures are converted into an index of the direction of hostility (DHOS).

Before giving the questionnaires to the sample, they were piloted on some trainees about to leave the scheme. This discovered that the HDHQ and WPAI had several constructs and phrases not easily comprehended by an educationally restricted population. For this reason some test-items were rewritten (for example, in the case of the WPAI 'Sunday Observance' was replaced by 'Going to church on Sunday', and 'Knowing right and wrong when born' for 'inbuilt conscience').

RESULTS

For the full sample, the mean SPM raw score was 36.5 (9.9). This corresponds to an IQ of 90 (SD 10). This figure is affected by the 11 *S*s with SPM raw scores < 25 (and thus with IQs supposedly < 75). Looking at the two-thirds of the sample with raw scores $\geqslant 37$, the subsequent IQ ranges from 90 to 117 (median IQ = 98). This is a considerable range, and may suggest reasons why training programs are difficult to conduct: trainees differ so broadly in ability that it is difficult to set standards suitable for the entire group.

At Table 1 can be seen means and standard deviations for the sample broken down by sex. It can be seen that female trainees have significantly lower *P* scores than the males ($P < 0.02$), as well as higher N ($P < 0.002$) and L ($P < 0.05$) scores. Females also show significantly lower scores on the AH subscale of the WPAI ($P < 0.005$), and on the AHO subscale of the HDHQ ($P < 0.05$).

At Table 2 can be seen the correlation matrix for the full sample. Only those correlations that explain a minimum of 9% of observed variance between two measures (i.e. an r of 0.30 or above) will be reported. It is evident that the SPM

Table 1. Means and standard deviations of psychometric measures by sex

	Females			Males			
	n	Mean	SD	*n*	Mean	SD	*P* <
Standard progressive matrices	51	34.6	9.8	43	38.4	9.8	NS
Mill–Hill vocabulary *B* scale	36	21.2	5.0	27	22.0	3.6	NS
Psychoticism	50	5.0	3.0	44	6.9	4.1	<0.02
Extraversion	50	14.0	4.1	44	14.3	3.8	NS
Neuroticism	50	14.9	5.3	44	11.8	4.2	<0.002
Lie scale	50	9.3	5.1	44	7.5	3.8	<0.05
Conservatism	41	42.5	10.1	39	39.6	11.3	NS
Realism	41	36.7	5.6	39	37.4	6.6	NS
Militarism–punitiveness	41	10.7	4.1	39	10.3	3.6	NS
Anti-hedonism	41	11.2	2.9	39	9.1	3.4	<0.005
Ethnocentrism	41	9.0	3.9	39	10.1	4.8	NS
Religion–puritanism	41	10.0	3.9	39	9.2	3.8	NS
Active hostility	40	5.7	2.7	33	7.0	2.6	<0.05
Criticise others	40	6.5	2.4	33	7.5	2.3	NS
Projected hostility	40	3.2	2.0	33	3.9	2.0	NS
Self-criticism	40	6.1	2.2	33	5.4	2.0	NS
Guilt	40	3.5	1.8	33	3.9	1.5	NS
Total hostility	40	24.9	6.8	33	27.8	7.1	NS
Direction of hostility	40	−5.4	6.9	33	−5.8	6.2	NS

All comparisons by independent-subjects *t*-test.

Table 2. Correlation matrix of all experimental variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean	SD
Non-verbal "g"																					
1 Standard Progressive Matrices		0.44***	−0.04	−0.09	−0.07	−0.39***	−0.35***	0.15	−0.21*	−0.41***	−0.27**	−0.20*	−0.07	0.02	−0.28**	−0.06	−0.06	−0.14	0.25*	36.5	9.9
Verbal IQ																					
2 Mill–Hill Verbal Part B			0.06	−0.10	0.10	−0.46***	−0.54***	−0.03	−0.31**	−0.38**	−0.43***	−0.48***	0.15	−0.04	−0.16	0.10	−0.11	−0.01	0.24*	21.6	4.4
Eysenck Personality Questionnaire																					
3 Psychoticism				0.01	−0.02	−0.23*	−0.06	−0.03	−0.14	−0.13	0.19*	0.09	0.38**	0.40**	0.39**	−0.02	0.11	0.42***	−0.18	5.9	3.7
4 Extraversion					−0.06	−0.09	0.04	0.13	0.19*	−0.02	0.01	0.11	0.22*	0.18	−0.03	−0.11	0.09	0.13	−0.09	14.1	4.0
5 Neuroticism						−0.17	0.00	−0.22*	0.10	0.15	−0.10	−0.07	0.22*	0.20*	0.18	0.42***	0.36***	0.42***	0.18	13.5	5.0
6 Lie scale							0.53***	−0.25*	0.35***	0.51***	0.26*	0.22*	−0.33**	−0.32**	0.07	−0.17	−0.12	−0.30**	−0.32**	8.4	4.5
Wilson–Patterson Attitude Inventory																					
7 Conservatism								−0.08	0.67***	0.61***	0.62***	0.47***	0.02	0.01	0.15	0.17	−0.10	−0.02	−0.52***	41.0	10.7
8 Realism									0.14	−0.37***	−0.29*	−0.42***	−0.01	0.12	−0.01	−0.02	−0.01	0.02	0.13	37.1	6.1
9 Militarism-punitiveness										0.27**	0.36**	0.12	0.03	0.03	0.11	−0.14	0.05	0.02	−0.29**	10.2	3.8
10 Anti-hedonism											0.22*	0.22*	0.08	0.01	0.14	−0.01	−0.03	−0.06	−0.59***	10.2	3.3
11 Ethnocentrism												0.06	0.05	0.18	0.26*	−0.09	0.02	0.14	−0.33**	9.6	4.4
12 Religion-puritanism													−0.03	−0.03	0.09	−0.06	−0.03	−0.02	−0.19	6.2	2.7
Hostility and Direction of Hostility Questionnaire																					
13 Active hostility														0.39***	0.40***	−0.00	0.24*	0.69***	−0.24*	6.2	2.7
14 Criticise others															0.28**	0.07	0.34**	0.68***	−0.33	7.0	2.4
15 Projected delusional hostility																0.23*	0.34**	0.69***	−0.24*	3.5	2.0
16 Self-criticism																	0.34**	0.47***	0.64***	5.8	2.1
17 Guilt																		0.65***	0.28**	3.6	1.7
18 Hostility																			−0.02	26.1	7.0
19 Direction of hostility																				−5.5	6.5

Significance: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Test	*N*
SPM	96
MHB	64
EPQ	96
WPAI	82
DHOS	74

Table 3. Age-related norms compared to male and female YTS trainees

	YTS			Norms				
	n	Mean	SD	n	Mean	SD	t	$P<$
Males								
P	44	6.9	4.1	540	4.6	3.3	3.65	0.001
E		14.3	3.8		14.5	4.3	0.33	NS
N		11.8	4.2		10.7	5.1	1.64	NS
L		7.5	3.8		6.1	3.8	2.35	0.05
Females								
P	50	5.0	3.0	590	3.0	2.6	4.57	0.001
E		14.0	4.1		13.0	4.1	1.66	NS
N		14.9	5.3		13.3	5.2	2.05	0.05
L		9.3	5.1		6.8	3.9	3.38	0.001

All comparisons by independent Ss t-test.

correlate significantly in the negative direction with L ($r = -0.39$, $P < 0.001$) and C ($r = -0.35$, $P < 0.001$). The SPM/C relation would appear to be particularly attributable to the AH subscale of the WPAI (SPM/AH $r = -0.41$, $P < 0.001$). The MHB correlates with the SPM at 0.44 ($P < 0.001$), and again significantly and negatively with L ($r = -0.47$, $P < 0.001$) and C ($r = -0.54$, $P < 0.001$). Median MHB/WPAI subscale correlation is -0.35 ($P < 0.01$).

P unsurprisingly correlates with the overall hostility score ($r = 0.42$, $P < 0.001$), with this relationship being attributable to the summated effects of the outwardly expressed forms of hostility (P/AHO $r = 0.38$, $P < 0.001$; P/CO $r = 0.40$, $P < 0.001$; P/PH $r = 0.39$, $P < 0.001$). N correlates with the total hostility score at 0.40 ($P < 0.001$), with the salient HDHQ subtest correlates being both, unsurprisingly, internally directed (N/SC $r = 0.42$, $P < 0.001$; N/GUILT $r = 0.36$, $P < 0.001$). In addition to correlating with the SPM, L also shows a strong positive correlation with C ($r = 0.53$, $P < 0.001$). The major explanatory WPAI variable for this is again AH ($r = 0.51$, $P < 0.001$). L shows a modest negative r with hostility ($r = -0.30$, $P < 0.01$) and DHOS ($r = -0.32$, $P < 0.01$). It appears that this relationship is mostly explicable in terms of the significant negative correlations between L and HDHQ subtest AHO ($r = 0.33$, $P < 0.01$) and subtest CO ($r = -0.32$, $P < 0.01$).

Other than the correlation of the total test score with its subscales, C appears to correlate with DHOS at -0.52 ($P < 0.001$), this being predominantly attributable to the AH/DHOS correlation ($r = -0.59$, $P < 0.001$).

At Table 3 can be seen t-tests comparing age-related norms for the EPQ to the YTS trainees, as broken down by sex. Both male and female YTS trainees are significantly ($P < 0.001$) higher in P than a normal sample of comparable age and sex. The same follows for L (males, $P < 0.05$; females, $P < 0.001$). YTS females also show significantly higher levels of N ($P < 0.05$) than a comparable sample.

DISCUSSION

The results presented above show that both verbal and non-verbal ability correlate with C. An earlier discovery, that the SPM and MHB correlate with L (Eysenck, 1971) was replicated. L correlates with C rather more highly than earlier results have shown, possibly because the range of scores exists predominantly amongst Ss with a IQ below 100.

The YTS trainees appear to be rather higher in P and N than a normal sample of similar age and sex. They also show rather less self-insight, if their L scores are considered. Attributing this to questionnaire acquiescence is doubtful; the EPQ has statements phrased in both positive and negative directions, so agreeing with all statements would reduce the S's overall score on the scale. Possibly lower-IQ Ss have difficulty answering absolutist ("Are all your habits good and decent ones?") questions when such items are nested in a series of questions requiring probablistic responses ("Do you tend to keep in the background at lively parties?").

From the observed correlation between the SPM and C, it would appear that Brand's explanation for shifts in global IQ is supported; those higher in C appear to have lower IQ as measured by a timed test. The MHB/C r of -0.54 ($P < 0.001$) would appear to further substantiate this theory, as the MHB was given timed to Ss, who themselves spent a maximum of 10 min on the task. Thus on verbal tests, more socially conservative Ss again show lower intellectual ability. This C measure does not follow conventional political party lines; in deprived parts of Edinburgh, political Conservatism is negligible. An alternative test of the global increase in IQ being a product in shifting levels of C would be to consider changes in performance on the WAIS at subtest, verbal/non-verbal subtotal, and g extraction level, in comparison to performance on more g-loaded tests such as the CCF or SPM, over time. Would it be the case that only the timed tests showed an increase in performance for the low-C S?

The high degree of hostility seen in the population could quite possibly be a product of poor standardisation of the HDHQ; McPherson (1988) reports that a population of Scottish women also show apparently elevated hostility scores, while Arrindell, Hafkenscheid and Emmelkamp (1984) have shown that age and social class affect the HDHQ, with older people and those from higher socio-economic groups tending to score lower. Normative data in the HDHQ manual involved only a small control sample, of 47 and 30 Ss respectively. It is clear that this author must add his voice to those of Phillip (1969) and McPhearson (1988) in emphasising the need for representative norms on the HDHQ, lest further users of the tested are misled.

Field work of the kind that this study reports is unusual these days, in that most reported research involves either samples of students or subjects who belong to a clinical group. Approaching a population of normal (if slightly below-average IQ) Ss enables one to address broad hypotheses if not the more specific ones. This study has provided evidence in favour of an individual difference explanation for the apparent rise in global IQ. It also provides norms concerning baselines of IQ, personality, attitudes and hostility amongst a sample of young adult more usually alluded to than actually assessed.

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